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Responses of Raptorial Birds to Low Level Military Jets and Sonic Booms

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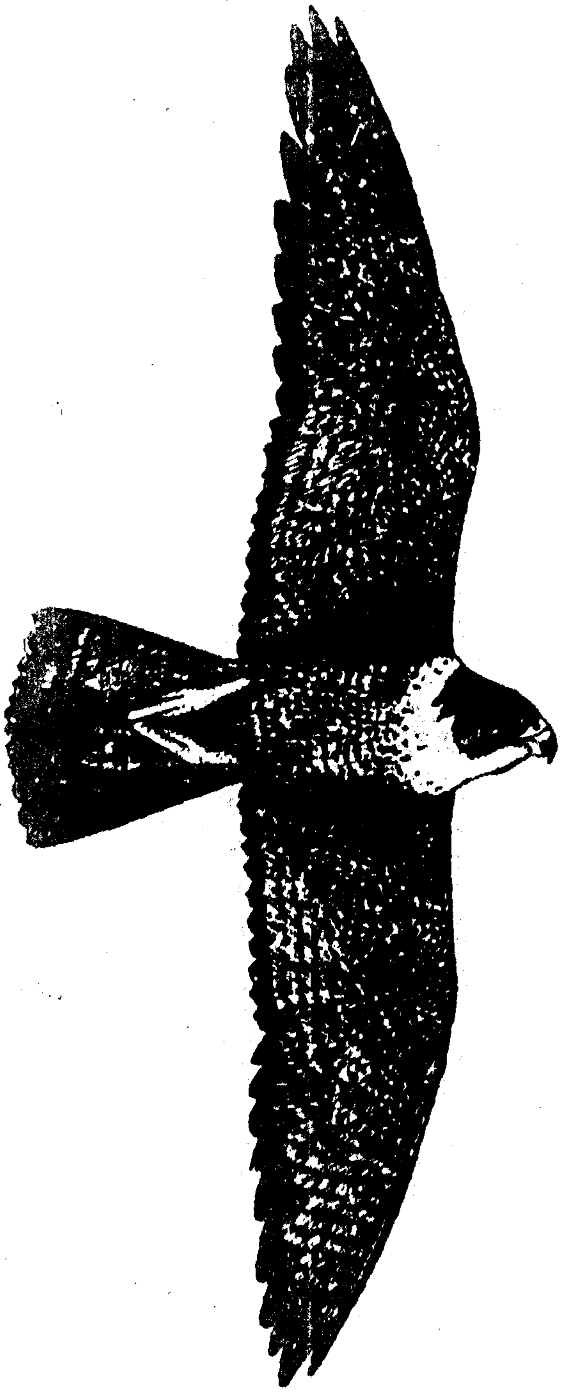

by
David H. Ellis

Institute for Raptor Studies: October 1981

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21

RESULTS OF THE 1980-1981 JOINT U.S. AIR FORCE-

U.S. FISH AND WILDLIFE SERVICE STUDY

by

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Arizona-Sonora Desert Museum
Engineering-Science, Inc.

Fieldwork Participation: ~~U.S.~~ Fish and Wildlife Service,
Institute for Raptor Studies,

FRONTISPIECE

A Recently Fledged Peregrine Falcon at Site 6

ACKNOWLEDGEMENTS

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Several biologists participated in the field. David Mindell deserves special commendation for his persistence with the heart rate monitoring system. The success of the 1981 experiments with the Prairie Falcon is largely due to his efforts.

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Finally, Catherine H. Ellis acted as contract officer for both years of the project, assisted occasionally in the field, and provided drafting and secretarial help in preparing this report.

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INTRODUCTION

In 1979 the U.S. Air Force and the U.S. Fish and Wildlife Service began formal endangered species consultation to determine the effects of low level military jet flights and sonic booms on nesting Peregrine Falcons (Falco peregrinus anatum) (Shotton 1980). The two year investigation reported below resulted from this consultation. The literature on broad spectrum animal responses to loud noises is rather extensive (Bell 1972, Bond 1971, Cottereau 1972, EPA 1971, Ewbank 1977, Fletcher and Busnel eds. 1978, Jehl and Cooper eds. 1980, National Academy of Science 1970, Rylander ed. 1972, Slutsky 1975). A review of this literature is not intended here, however, some generalizations are pertinent. Demonstrated effects on laboratory animals due to experimental noise are: changes in heart rate, increased irritability, and in one case, altered rates of certain types of maintenance behavior (EPA 1971). It is also possible to inflict permanent auditory damage in vertebrate organisms by subjecting them to a rapid series of extreme noise (Majeau-Chargois 1969). Stampeding in pinnipeds (seals, sea lions, and their allies) (Bowles and Stewart 1980: 112) and running, flying, and crowding (the pandemonium response) in domestic turkeys (Meleagris gallopavo) and chickens (Gallus domesticus) is sometimes observed following loud noise bursts especially if accompanied by startling visual stimuli (Bell 1972). Lynch and Speake (1978: 58), however, observed minimal responses (lasting at most 30 seconds) in wild turkeys (M. g. silvestris) to simulated sonic booms: they conclude "that sonic booms do not initiate abnormal behavior in wild turkey that would result in decreased productivity."

There is circumstantial evidence associating the 1969 near total (99%) hatching failure in Sooty Terns (Sterna fuscata) nesting on the Dry Tortugas Islands with concurrent booms (approximately 168 dB: 100 lb/ft^2) produced by supersonic military jets flying at "deck" level (reviewed in Bell 1972). Laboratory tests of the effects of high altitute sonic booms on hatching success have uniformly failed to detect negative effects due to the booms (Bell 1972, EPA 1971). Cogger and Zegarra (1980) failed to detect effects on oviposition time, shell weight or thickness, hatchability or viability in chicken eggs subjected to booms (156.3 dB, Peak flat) far in excess of those expected by high altitude flights but not as severe as conditions associated with the Sooty Tern hatching failure cited above.

Busnel (1978: 11) in reviewing the then available literature stated: "While the animal's first reaction to a new noise source ...is fear and avoidance, if his other sensory systems (optical, chemical) are not stimulated, the major vertebrates quickly learn to ignore the noise source." Schreiber and Schreiber (1980) reported that colonial nesting gulls (Laridae) and cormorants (Phalocrocoracidae) typically respond to noise bursts by the head-jerk action pattern: less often, incubating birds rise and walk a few steps. Non-nesting birds of the same taxa

typically spring into flight but quickly resettle. The Schreibers summarized their findings as follows: "we believe that in comparison to a human walking into a bird colony a sonic boom will have minimal effect."

Little published information is available on raptor responses to aircraft or sonic booms. It is known that raptors (especially territorial adults near the nest) occasionally attack slow-flying aircraft (e.g., Anon. 1978, Blokpoel 1976, Fyfe and Olendorff 1976). This should not be a problem with military jets (with the possible exception of loitering A-10's). There is also a remarkable account (Jackson et al. 1977) of a female Marsh Hawk (Circus cyaneus) actively hunting on a United States Navy bombing range and concentrating its forays in the target zone while TA-4 jets at ca 1800 feet altitude were dropping 25 pound practice bombs at one minute intervals. The closest explosion occurred within 200 feet of the actively hunting bird. At some military bases raptors congregate to forage along cleared aircraft runways and thereby pose a hazard to air traffic (pers. comm. Jeff Short and Geral Long of the U.S. Air Force Bird Aircraft Strike Hazard (BASH) Team).

Two studies were specifically designed to test the effects on aircraft flights on nesting birds of prey. Platt (1975 in Platt unpubl. 1977) observed the immediate responses and nest site reoccupancy rates at 22 Gyrfalcon (Falco rusticolus) eyries subjected to 51 helicopter overflights. He found that all birds were disturbed by craft at 160 m, none at 600 m, and none were disturbed by noisy craft when they were out of sight over the cliff rum. Disturbed birds quickly resumed normal activities following the overflights and no pairs were known to have abandoned nesting attempts due to the helicopter passes. However, none of the five sites tested in 1974 were reoccupied in 1975. The sample size is very small but the data suggest a long term avoidance reaction in disturbed Gyrfalcons.

In a more intensive testing situation Snyder et al. (unpubl. 1978) quantitatively experimented with a nesting colony of Snail Kites (Rostrhamus sociabilis) in Florida to determine responses to frequent (one craft every 5-10 minutes), low-level (most flights were 500-750 ft agl) jet (commercial passenger carriers and smaller craft) passes. Kites frequently interrupted activities to watch the aircraft for a few seconds, but significant negative responses were not noted. The study also included observations of four kite colonies near the jetport at Barranquilla, Colombia. Here again no significant responses were noted. One colony of kites (at least 13 pairs) nested only 420 m from the end of the runway.

The following is a summary of the possible negative effects of the study stimuli on nesting raptors: (1) direct interruption of behavior leading to exposure of eggs or young to inclement weather, (2) physiological stress of parents or young leading to reduced reproductive performance, (3) eyrie abandonment (immediate and long term), (4) accidental death of young prematurely fledging when startled, and (5) other short-term behavioral responses. ~~Cade (1960: 188) reported that he several times observed startled adult falcons kick eggs out of the nest scrape: this factor should also be considered.~~

The goals of this study were to determine which if any of the possible adverse responses described above were operative in the case of peregrines nesting in Arizona. The approach was to experiment first with surrogate species and thereby minimize the possibility of disrupting Peregrine Falcon breeding efforts. By using a broad range of surrogate species, we also hoped to determine if any of these species were hypersensitive. The objective in many of the experiments was to simulate a worst case situation (i.e., booms louder and oftener than would be expected and repeated passes with aircraft oftener and closer than would be expected even in extreme conditions in the wild). The rationale behind this approach was as follows: if severe behavioral responses could not be generated in the worst case experiments, then we could logically conclude that responses to less intense stimuli would be less severe.

To satisfy the objectives of the study we gathered several types of data. First we observed behavioral responses for most of nearly 1000 jet passes and over 100 real or simulated booms at 40 Falconiform breeding sites of 8 species (Table 1). The outcome of many of the trials (where the birds were visible) is included in the Appendices. Second, encouraged by good fledging rates at test eyries in 1980, in 1981 we subjected four pairs of Prairie Falcons (Falco mexicanus) to extreme test situations (i.e., the daily maximum for jet passes was 42 at one eyrie, and 23 booms at another) during the courtship-incubation phases of the nesting cycle when they were most likely to abandon (Fyfe and Olendorff 1976). Third, via a telemetry egg we monitored heart rate changes in one pair of incubating Prairie Falcons subject to heavy stimulus loads. Fourth, in 1981 we revisited all sites tested in 1980 to determine reoccupancy rates. Finally, to avoid conducting all of our experiments with wild birds with unknown histories of prior experience with the test stimuli, we tested two juvenile Austral Peregrine Falcons (F. p. cassini) with known histories of experience with loud noise and aircraft.

Because heavily contaminated Peregrine Falcons were likely to exhibit behavioral abnormalities confusing the results of the study, we gathered data on productivity and pesticide contamination. Three measures were used to evaluate the health and degree of pesticide contamination of the Arizona population. Thirty-one Peregrine Falcon reproductive efforts were followed to determine fledgling productivity. Eggshell fragments were gathered at eyries. Thickness measurements for these fragments give a second measure of the effects of a pesticide load in the adults (Peakall 1976). Results from the third measure (lipid extraction--pesticide analysis) are available only for the 1978 data.

Because sound is a multifaced phenomenon and because of widespread inconsistency in reporting noise parameters in the literature, Table 2 is included to introduce the reader to the noise levels discussed in this study.

TABLE 1

TWO YEAR TOTALS FOR EXPERIMENTAL FLIGHTS AND BOOMS

Year	No. Species	No. Eyries	No. Passes	No. Booms
A. Experiments with Wild Raptors				
1980	8	22	239	22
1981	4	18	675	83
B. Experiments w:.th Captive Austral Peregrine Falcons				
1981	male	N.A.	35	9
	female	N.A.	29	7
C. Grand Totals				
2 years	8	40	978	121

TABLE 2

NOISE LEVELS RELEVENT TO MILITARY JET OPERATIONS

I. Sound pressure is expressed in decibels (dB) and instantaneous sounds are also expressed in pounds per square foot (psf).

A. Each 3dB increase is equivalent to a doubling of sound intensity.

B. 0dB = 4.17×10^{-7} psf.; 1 psf = 127.6 dB; 1 atmosphere (2116 psf.) = 194.1 dB.

II. For sonic booms and artillery blast, sound pressure levels (peak and C-weighted) and psf. are related as follows:

A. x dB (peak) = $(20 \cdot \log_{10} y$ psf) + 127.6.

B. x dB (c) = $(20 \cdot \log_{10} y$ psf) + 101.6

C. Peak noise levels are converted to C-weighted values by subtracting 26dB from the peak value.

III. Examples of sonic boom sound pressures expressed as dB peak values and psf:

A. F-15 Eagle at Mach 1.1 (1.1 x speed of sound) at 15,000 feet delivers an average sound overpressure of 139 dB (Peak) = 3.7 psf.

B. F-104 Starfighter at Mach 1.4 at 42,000 feet was measured at 134 dB (Peak) = 2.1 psf.

C. Normally high altitude sonic booms range between 128 and 142dB (Peak) = 1-5 psf.

D. Extreme low level sonic booms could approach 168dB (Peak) = 100 psf.

IV. Examples of low level jet aircraft overpressures, expressed as dB(A) values:[1]

A. F-15 Eagle at crusing RPM 200 feet overhead = 97 dB(A).

B. A-10 Thunderbolt at crusing RPM 500 feet overhead = 100 dB(A).

[1] Note that psf and dB (Peak) scales are not used for non-instantaneous (continuous and intermittent) noises.

METHODS

THE EXPERIMENTAL BIRDS

In 1980 we experimented with a wide range of raptorial birds (Table 3). Early in the season we concentrated on surrogate species but when we were confident of the range of likely responses we tested several peregrine eyries with a modest number of sorties and booms. In 1981 we concentrated our attention on the Peregrine Falcon and its closest Arizona kin, the Prairie Falcon. All phases of the breeding cycle were tested even in the peregrine but we concentrated on the courtship and incubation phases in the Prairie Falcon. Stimulus loads are reported for the two principle study species in Figures 1 and 2. They are also reported on an eyrie by eyrie basis for all raptors in the species accounts in the Results section.

In an effort to correlate Peregrine Falcon behavioral response levels with pesticide loads in the adult females, we visited many eyries repeatedly through the breeding season to determine productivity (Ellis and Fackler *in press*, Ellis and Grubb *in prep*.). Later we collected eggshell fragments and addled eggs at many of the study eyries (Table 4). We waited until after the young had fledged for several days, entered the eyrie using standard climbing aids, and sifted the shell fragments from the floor of the eyrie. Later the fragments were measured for thickness as an indication of the degree to which they had suffered pesticide induced shell thinning. This method was first employed for the California Condor (*Gymnogyps californianus*) by Kiff et al. (1979).

While it is impossible to be certain of the level of prior experience of the wild birds observed in the study, it is possible to state that the birds were or were not nesting in areas where they were likely to receive sonic booms and/or nearby jet passes. These rough evaluations are presented in Table 3. Importantly, none of the test Peregrine Falcons were nesting in super sonic military operations areas (S-MOA). Only sites 4 and 5 were likely to be subject to infrequent low level jet traffic within 500 m of the eyrie. All Prairie Falcon eyries were in S-MOAs but only sites 1 and 11 could expect regular close jet traffic. Both of these sites were in extremely active low level jet corridors: both could expect frequent passes within 400 m.

Experiments were also performed with two captive Austral Peregrine Falcons taken as nestlings from an eyrie in the Andean foothills in central Argentina in mid November 1980. The birds were held in USDI supervised quarantine in central Utah and transferred to Arizona in early April 1981. The birds were trained for falconry and flown free at bagged Rock Doves (*Columba livia*). In late August 1981 the bird's reactions to extreme booms and very near aircraft were tested while the birds were held tethered, while feeding, and, for one bird, while in free flight below A-10 aircraft. Some low level passes were timed in an effort to interrupt hunting stoops (dives).

TABLE 3

EXPECTED FREQUENCY OF LOW LEVEL JETS[1] AND SONIC BOOMS AT THE STUDY EYRIES[2]

Species	Site	Expected Frequency of Low Level Jets			Expected Frequency of Sonic Booms		
		V-Inf	Infreq	Freq	V-Inf	Infreq	Freq
Cooper's Hawk	1	+			+		
Black Hawk	1		+				+
	2	+			+		
	3	+			+		
Harris' Hawk	1		+				+
Zone-tailed Hawk	1	+			+		
	2	+			+		
Red-tailed Hawk	1		+				+
	2		+				+
	3		+				+
	4		+				+
Golden Eagle	1			+		+	
Prairie Falcon	1			+			+
	4		+				+
	7		+				+
	10		+				+
	11			+			+
	12		+				+
Peregrine Falcon	1	+			+		
	2	+			+		
	3	+			+		
	4		+		+		
	5		+		+		
	6	+			+		
	7	+			+		
	8	+			+		
	23	+			+		
	24	+			+		
	25	+			+		
	27	+			+		
	28	+			+		

1 High level jet activity (3000 m or greater) can be expected at least infrequently all across Arizona.

2 Frequencies reported here are approximations of the number of times aircraft normally pass within 500 m of the eyrie. Values are based on the occurrance of "uninvited" jet activity at the study eyries. The column heading abbreviations are: V-Inf (very infrequent) = 1/month, Infreq (infrequent) = 1/week, Freq (frequent) = 1-5/day.

FIGURE 1

STIMULUS LEVELS AT PRAIRIE FALCON EYRIES

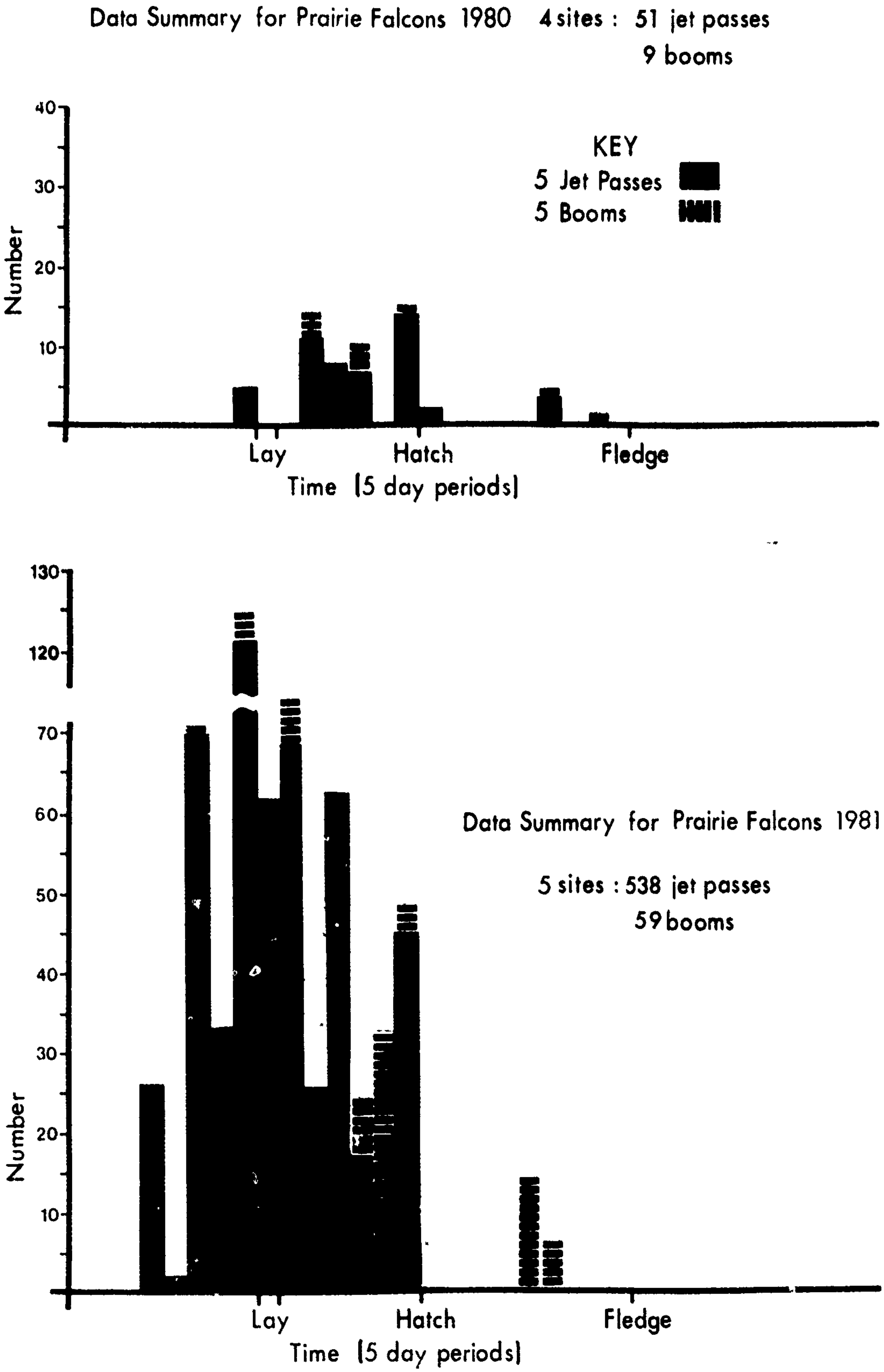
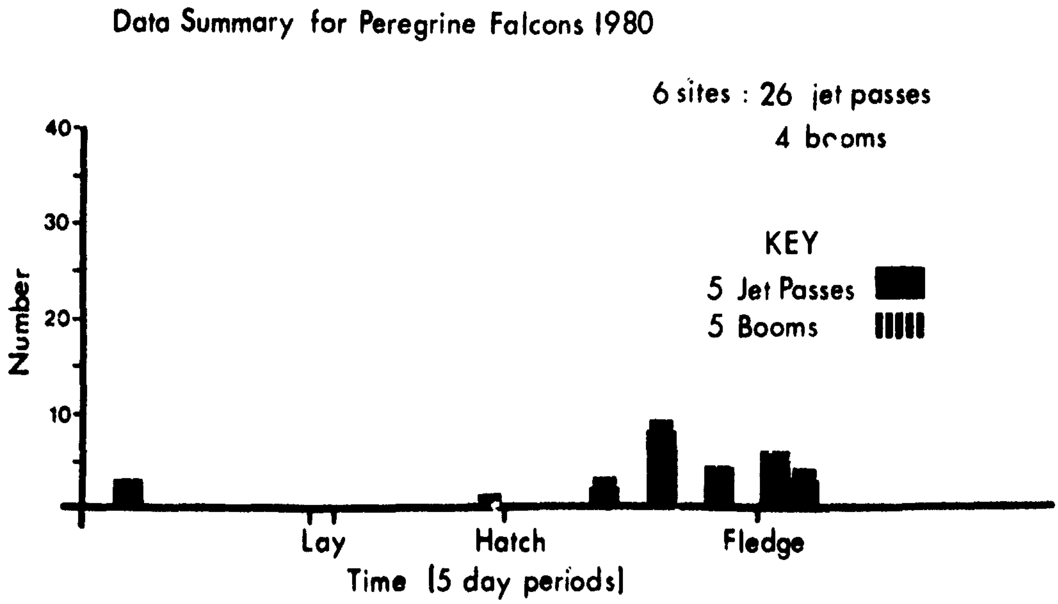


FIGURE 2

STIMULUS LEVELS AT PEREGRINE FALCON EYRIES



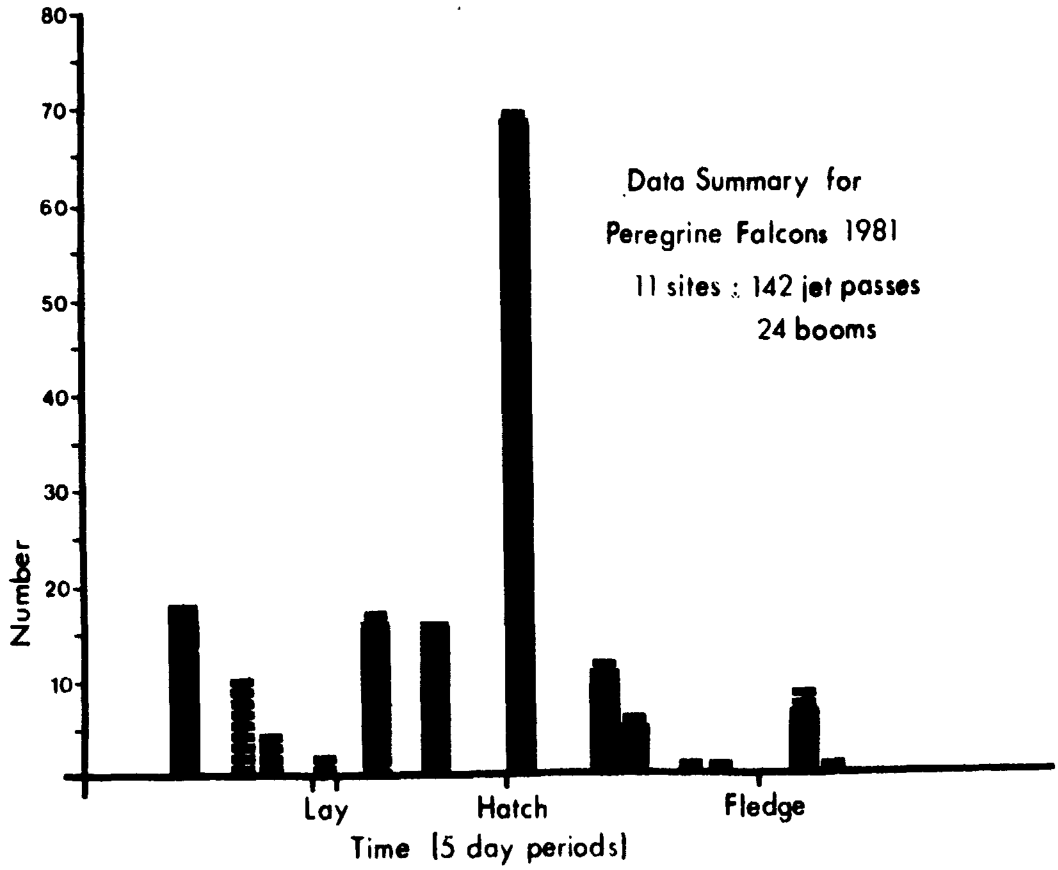


TABLE 4

EGGSHELL THICKNESS[1], PESTICIDE LEVELS, AND PRODUCTIVITY AT PEREGRINE FALCON EYRIES IN ARIZONA

Site No.	1978 Prod	78 Shell Thickness N (Range-mm) $\bar{x}$	1979 Prod	79 Shell Thickness N (Range-mm) $\bar{x}$	1980 Prod	80 Shell Thickness N (Range-mm) $\bar{x}$	1981 Prod	81 Shell Thickness N (Range-mm) $\bar{x}$
1	-		-		≥3		≥1	
2	2		≥1		≥1		1	15(.309-.390).340
3	2	20(.288-.375).320[2]	?		0		≥3	
4	0	10(.350-.371).363[3]	?		≥2		0	
5	3		?	15(.320-.381).341	3		0	
6	3	10(.333-.371).353[2]	?		2	15(.362-.382).373	3	10(.338-.394).369
7	-		-		0		≥1	
8	-		3		4		4	25(.275-.400).308
11	1	10(.308-.320).314	2		?		0	
12	0		-		-		-	
13	-		≥2		?		0	
23	0		?		0		0	
24	0		?		2	15(.329-.356).339	4	10(.281-.356).339
25	0		3		≥2	16(.301-/337).317	≥3	
26	-		-		0	15(.312-.349).327	0	
27	2	10(.288-.343).314[2]	?		?		2	
28	2		?		≥3	15(.296-.389).314	?	10(.313-.338).325
29	0		?		0		?	

1 Measurements reported here are fo_ shells with membranes as measured with a bench comperator thickness gague. Pre-1947 California shells with membranes averaged 0.370 using the same device (Lloyd Kiff, pers. comm.). Shell thickness measurements of many fragments were made without shell membranes. To these values 0.088 mm was added, the mean thickness of shell membranes for 10 pre-1947 California Peregrine Falcon eggs.

2 Lipids extracted from these samples were analyzed for DDE and DDT courtesy of David Peakall, Canadian Wildlife Service. DDE and DDT were not detected (<1 ppm).

3 Thickness values for an additional whole (addled) egg from this site were N=10, R=.369-.375, $\bar{x}$=.373.

For these experiments the birds were transported to the same elevated ridge where they had been flown daily for the past month. They were tethered to their customary perches and allowed to rest while we assembled equipment for the coming tests. After radio contact was established with the approaching craft the female was readied for flight (if she was to be flown free under the craft). The aircraft then swept back and forth across the ridge directly over the falcons until the test was complete.

The falcons' prior experience with aircraft was as follows. While in Argentina they likely had no experience with low level aircraft. While in transit to Utah they were held in a darkened chamber and shipped by air cargo. In Utah they observed occasional high level aircraft traffic. At the Arizona holding facility aircraft traffic was regular but at mid to high altitudes. They had no known experience with low level aircraft prior to August when they were subjected to repeated experimental passes.

Prior to the sonic boom experiments in August 1981, the falcons presumably had experience with loud jet noises while in transit from Argentina to Utah and in May and June we subjected the birds to a series of shotgun blasts muffled by the walls of a motor vehicle. The birds were closely observed during these explosions and showed at most minor alarm. Finally, the birds were conditioned to travel in motorized vehicles in Argentina and Arizona and thereby learned to ignore passing vehicles. They, however, retained fleeing responses to alarming stimuli such as a rushing dog, strange humans, cats, lawn mowers, etc.

THE STUDY AREA

Simulated sonic booms were generated at peregrine eyries all across Arizona. Low level flights were arranged only in the southern third of the state. Responses to jet caused sonic booms were observed at a Black Hawk (Buteogallus anthracinus) nest in the Wickenburg Military Operation Area (MOA) and at Prairie Falcon eyries in the Sells MOA and the nearby Fort Luke Air Range. The Red-tailed Hawk (Buteo jamaicensis) and Harris' Hawk (Parabuteo unicinctus) nests were located in the same two areas. The remaining Black Hawk sites, the Zone-tailed Hawk (Buteo albonotatus) eyries, Cooper's Hawk (Accipiter cooperii) nest, and the peregrine eyries were located away from but near low level flight corridors and/or in the Tombstone and Williams MOAs.

THE STIMULI

Early in the study we learned that jet passes greater than 500 m from the birds consistently failed to elicit significant responses (typically birds watched distant craft for a few seconds), hence, all passes tallied in this report were for jets 500 m or less from the birds or eyries. Six types of craft were involved in the study (Table 5). The A-10 was used for most tests because of its ability to maneuver close to eyrie cliffs. The A-7 has near comparable maneuverability but we found it difficult to arrange the large number of sorties required in the study. All passes less than 60 m from the cliffs were accomplished with A-10 and A-7 craft. F-104 and A-4 sorties were never called in and our

TABLE 5

NOISE LEVEL COMPARISONS FOR AIRCRAFT INVOLVED IN STUDY[1]

Aircraft Type		Noise Levels at Selected Slant Distances (dBA peak values) 200' (61m)	500' (152m)	1000' (305m)	No. (%) of Test Passes
A-4	(Skyhawk)	104	94	86	2 (0)
A-7	(Corsair II)	101	92	85	74 (8)
A-10	(Thunderbolt)	110	100	92	883 (90)
F-4	(Phantom)	114	105	98	14 (1)
F-15	(Eagle)[2]	97	89	82	0
F-104	(Starfighter)	110	101	94	9 (1)

1 Sound levels are for aircraft at normal cruise RPM values and are rounded to nearest whole dB value reported by Speakman et al. 1978.

2 The F-15 is included for comparison. This aircraft was involved in the study only as a source for high altitude sonic booms.

observations of these craft were incidental to other activities. The F-15 was sometimes seen in the Fort Luke Air Range and environs but was never directly invited to pass near a test eyrie. F-4 craft were involved in the first year of the study, but, because of higher flight speeds, they were unable to execute passes close to breeding sites as required in the study.

To stimulate a worst case situation, in 1981 we often arranged for long series of jet passes at test eyries (see stimulus column in Appendix I). In an extreme case at one Prairie Falcon eyrie (Site 12) eighteen A-10 passes occurred in less than nine minutes. More typically 5-10 passes occurred in a test bout.

Noise levels at selected distances are presented in Table 5 for craft in normal cruise flight. Recall (from Table 2) that each increase of 3 dB equals a doubling of sound energy. From Table 5 it appears that the F-15 is a very quiet craft while F-4 and A-10 craft are very noisy. Actually when F-15 craft move from cruise to high thrust power settings they become much more noisy than an A-10 at maximum power. The table is intended to present a small portion of the range of noise levels of study craft and to show that all craft are quite loud when nearby.

Three devices were used to simulate sonic booms (Table 6). All produce impulse noises comparable in peak energy to supersonic jets in the mid to high altitude range. None generate the long duration booms (50-100 msec) normally associated with a jet induced sonic boom (Maglieri and Henderson 1973). The tabulated values are presented for use in evaluating the responses of the birds detailed in Appendix II. Aircraft generated booms were never scheduled and hence were never measured directly. The loudest jet induced booms were judged approximately equal to a mortar salute at perhaps 100-200 m.

The mortar salute was the most practical device to backpack to remote locations (i.e., each explosive weighed only about 200 gms and the launching tube, constructed of a 10" section of 3" diameter PVC plastic pipe capped at one end by a no. 303 food storage can, weighed only about 120 gms)[1]. Unfortunately, because the post launching explosion occurred ca 120 m aloft, it was often difficult to conceal from the subject birds. In addition, the quieter launching explosion sometimes resulted in minor grass fires, hence our inability to use it where forest fires were likely.

[1] Note: The recommended launching device for a 3" mortar salute is a 3½" diameter, thick walled, steel pipe capped at one end by 3/16" steel plate and buried one foot in compacted earth before firing. For safety reasons we do not recommend the use of the light weight launchers employed in this study. At least three launchers tore apart during the study endangering the researchers.

TABLE 6

SOUND LEVELS GENERATED BY BOOM SIMULATING DEVICES USED IN STUDY [1,2]

Mortar Salute[3]				Shotgun[4]				Propane Cannon[5]			
$\bar{x}$ dB	(m)	No.	Range	$\bar{x}$ dB	(m)	No.	Range	$\bar{x}$ dB	(m)	No.	Range
								148	(13)	N=7,	R=146-151
141	(30)			140	(30)						
				131	(50)						
137	(70)										
				130	(80)						
134	(100)							129	(100)	N=5,	R=126-134
				124	(150)			124	(150)	N=6,	R=120-126
139	(200)			117	(200)	N=2,	R=114-119	122	(200)	N=6,	R=121-126
126	(300)							117	(300)	N=5,	R=116-121
125	(400)							113	(400)	N=7,	R=110-116
123	(600)										
114	(1100)	N=2,	R=111-116					90	(1100)	N=10,	R=98-103

1 All sound measurements were made with a Gen Rad 1982 Precision Sound Level Meter (settings: WTG, flat peak). Measurements near 140 dB were taken with a 10 dB attenuator to avoid exceeding the capacity of the meter.

2 Distances chosen for each device are comparable to device-bird distances reported in Appendix II.

3 Mortar salutes were 3 inches in diameter (actually 2½" diameter x 3 3/8" long) with a 2 foot, 2 second fuse. The reported dB values for 30, 70 and 100 m are lower than actual because the explosive detonates after being propelled to ca 110 m aloft. Mortar weights were: $\bar{x}$=184 gm, R=178-190 gm (N=8).

4 All experimental blasts were made using a 12 gauge shotgun with 30" barrel and a 3 3/4 dram game load fired at 15-25° from directly toward bird, or, in this case, the sound meter.

5 Model M3 Scare Away Gun supplied by Reed Joseph International Co., Greenville, Mississippi.

THE DATA GATHERING SEQUENCES

A major obstacle in conducting both experimental jet passes and booms was our inability to standardize the experimental situation. First, we operated on a non-interference basis with the U.S. Air Force (i.e., we could not schedule additional flights to satisfy the demands of our experimental design). Also, we did not have good controls over individual experiments because of variations between pilots, topography, birds, aircraft, and boom generating devices. For example, one instructor pilot might make repeated passes with his student following close in a second craft while another would make one or more distant passes with his student far afield. Some eyrie situations allowed for very close approach, others made it unsafe for an aircraft to come closer than 100 m. At some eyries it was possible to conceal the observers and the boom producing device. In other situations it was impractical to hike to the eyrie with anything other than the light weight mortar salutes which when fired often exposed the birds to a visual as well as audible stimulus. In the Appendices the extraneous visual stimuli are reported in each case where they likely influenced the outcome of the trial. Because of this variability in stimulus situation, few trials are directly comparable: for this reason each trial is presented as a separate anecdote in the Appendices.

An attempt was made, however, to standardize the data gathering sequence. Where possible the following steps were employed. The observer entered the blind or approached a distant observation point at least 30 minutes before an anticipated flight or boom. He then assembled observing and recording equipment including stopwatch, digital watch (displaying seconds), cassette tape recorder, binoculars and/or telescope, UHF radio (if aircraft were expected), notebooks, and boom generating devices. During the rush of a stimulus-response sequence, data were taken on the tape recorder while periodically announcing time to the nearest second. During many tests two observers gathered the data. One observer handled the UHF radio to guide the pilots near the eyrie and watch birds aloft to record behavior, estimate bird-aircraft distances[1], and avert collisions. The second observer watched stationary birds and made a voice record of the episode. Between experiments data were transferred to form sheets and the recorder was readied for the next test.

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[1]Distances of the aircraft from the eyrie, ground, flying birds, etc. were estimated by several means: (1) the pilots often relayed their above ground level (agl) readings, (2) agl estimates were also made directly by extrapolation from the heights of key topographic features (measured from topographic sheets) near which the craft passed and by estimating from the known dimensions of the aircraft, and (3) horizontal distances were estimated by projecting the path of the craft onto known terrain. High altitude flights (>500 m) were neither estimated nor reported herein. Passes close to cliffs and trees are believed to be accurate within 10-15 m based on comparison of our estimates with photographic records. Passes >200 m overhead were generally estimated only to the nearest 50 m.

A data gathering sequence for the Austral Peregrine Falcon experiments was much like that for the wild birds but during the trials one or both birds were tetherd to perches with the observers within 20 m of the birds (except when a falcon was aloft). For some experiments three observers were occupied handling the trained falcon, releasing pigeons, describing the behavior of the second (tethered) falcon, and communicating with the pilots.

HEART RATE MONITORING AT PRAIRIE FALCON SITE 11:81

In 1981 we used a heart rate (HR) telemetering egg designed for the study by Stuart Enterprises (P. O. Box 2219, Grass Valley, California 95945) to gather data on changes in heart rate associated with the subject stimuli. The system consists of two major subsystems: (1) the transmitter, sensitive to very small motions, mounted within an eggshell of the proper size and (2) the receiving system consisting of elements to receive, process and record the transmitted data. Figure 3 shows the various elements of the egg and receiving subsystems.

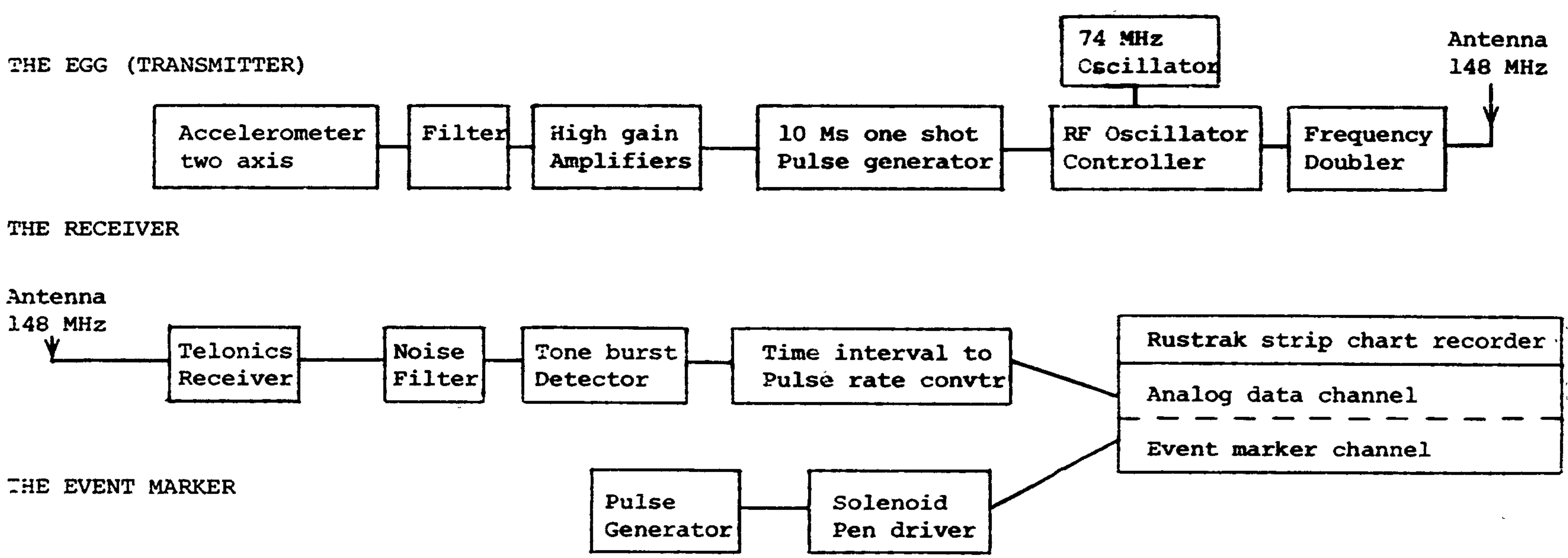
Egg Description

The HR sensor consists of a sensitive biaxial accelerometer, the output of which is amplified by two high gain amplifiers and then filtered to remove high frequency noise and some motion artifacts. The filtered signal actuates a pulse generator. The RF signal generator is controlled by a 74 MHz crystal oscillator, the frequency of which is doubled (to 148 MHz) and radiated by a three turn tuned coil antenna to the receiving system. The pulse generator activates the transmitter for a 10 milisecond burst each time it is actuated. The power for the egg subsystem comes from a three volt 600 mAH battery. The transmitter is embedded in a vinyl-paraffin wax mixture and encased in sawed open halves of the eggshell. The two halves of the shell are held together by a small amount of urethane based epoxy. A small hole through the shell allows access to a screw driven gain control, thus allowing the user to adjust the sensitivity of the accelerometer and thereby prefilter lower level noise while retaining the desired heart rate signal.

When the egg was in close mechanical contact with the nesting adult, the motion of the heart shook the egg exciting the accelerometer and causing an RF pulse to be transmitted at 148 MHz. The pulse was detectable by the receiving equipment at up to 1 km. When the adult was settled on the nest the signal could be recorded on the Rustrak recorder or be simultaneously counted directly from the audible receiver signal. During the stimulus episodes the adult's responses could be monitored as long as the adult was in close contact with the telemetering egg. In practice, useable HR data was received about 5% of the time with two telemetering eggs and two natural eggs in the nest. System disfunction was caused by the incubating adult not being in sufficiently close contact with the telemetering egg to generate a pulse.

FIGURE 3

ELECTRONICS SUBSYSTEMS BLOCK DIAGRAM FOR THE HEART RATE TELEMETERING EGG



Receiving System Description

The receiving subsystem consists of a two element yagi antenna coupled to a sensitive triple conversion super heterodyne receiver (Telonics TR-2-148/150) to form a very sensitive RF detector. The transmitted pulse signal detected by the TR-2 is then processed by the time interval to a pulse rate converter (Stuart Enterprises RHR-2). This circuit performs the function of transforming the time interval between transmitted pulses into a linear rate signal suitable for activating a strip chart recorder (Rustrak). This conversion is performed to provide a better resolution of small changes in HR at rates higher than would be possible if only the time interval were recorded.

The second data channel on the Rustrak served as an event marker for recording the timing of jet passes, booms, and other short term events.

The receiving subsystem is mounted in a sealed aluminum carrying case 46 x 22 x 17 cm. The unit, powered by a 20 Amp Hour 12 volt DC Gel-Cell, is capable of continuous operation for 30 days without recharge. The receiving subsystem including battery weighs only 15 kg. All case penetrations are sealed with silicone rubber compound to make the unit watertight.

The system was calibrated first by placing the egg next to a tethered Rock Dove then adjusting the gain until we received the HR but little background noise. Next the egg was placed in a Great Horned Owl (Bubo virginianus) eyrie and adjustments were made until the biologists gained familiarity with the system's abilities. On 29 March, one egg was stippled to resemble a falcon egg, then placed in the Prairie Falcon eyrie. The site then contained 3 natural eggs. Because data were being transmitted only 1-2% of the time, on 8 April we added a second telemetering egg to the clutch. It was thereafter possible to receive data ca 5% of the time. When the eggs were removed (on 24 April, ca 1 day before hatching) at the conclusion of the experiments, only two natural eggs remained: large fragments of the third egg lay on the cavity floor. Two large young were present in the nest cavity when it was last visited on 19 May.

When the incubating falcon was in close contact with one of the telemetering eggs (as evidenced by the presence of a steady HR signal) we tested the falcon's responses by generating booms and approaching the eyrie on foot and in a motor vehicle. It proved impractical to have aircraft loitering in the area waiting for the falcon to readjust to a favorable incubation position so very few HR data were gathered during jet passes.

CLASSIFICATION OF BEHAVIORAL RESPONSES

Figure 4 is constructed from observations of raptor responses to a wide range of disruptive environmental stimuli. Some of the possible responses listed in the figure were never observed during the study.

FIGURE 4

SHORT TERM RESPONSE ALTERNATIVES TO DISRUPTIVE STIMULI[1]

Degree of Disturbance →	Behavioral Response Alternatives: Insignificant	Significant	Severe
ADULTS			
Stimulus ↓	Alarms Alerts Interrupts high pr. behav. Interrupts low pr. behav.	Protest Calls Cowers Flies Out	
Low Priority Pre-stimulus Behavior —— High Priority	Ignores		Flees (flight)[2] Delays Return Abandons Site
NESTLINGS			
Stimulus ↓	Alarms Alerts Interrupts high pr. behav. Interrupts low pr. behav.	Protest Calls Cowers Flees (on nest)	
Low Priority Pre-stimulus Behavior —— High Priority	Ignores		Fledges Prematurely

[1] Definitions of behavioral responses:

Alerted: feathers sleeked for less than 10 seconds if at all, bird interrupts other activities briefly and watches stimulus source.

Alarmed: feathers sleeked, bird intently looks at stimulus source or looks about rapidly turning head in search of stimulus.

Cower: bird crouches (flight intention movements evident) and remains still for at least a brief moment or more often longer.

Protest call: bird protests vocally using same call given at approach of avian predator.

Flies out: difficult to interpret, the bird may either circle out to gain a better view of stimulus situation or to prepare to flee.

Flee: nestlings run to sheltered portion of breeding structure: adults fly out and directly away from stimulus.

Delayed return, Abandonment and Fledges Prematurely: self evident.

[2] Eggs or tiny young may be dislodged by a fleeing adult. This, however, would represent an accidental not a behavioral response (the response is the act of fleeing) hence its omission from the figure, but because of this possibility the act of fleeing (adult) is here classified as a severe (i.e. progeny endangering) response.

Some subjectivity is required in interpreting raptor responses: more subjectivity is required in deciding if the observed responses are severe or less significant. My designations in Figure 4 are estimates o' the degree to which the birds are disturbed when they so behave. My basis for judgement is as follows: if a bird responds as for a normal natural disturbance (e.g., a large predator in the vicinity) then the response should be designated "significant" but not severe. If, however, the bird's behavior signals that it would likely fail in its reproductive effort if like harrassment were continued, then I judged the response as indicative of severe disturbance. For young birds, severe responses are those which would likely have resulted in death.

Delayed or long term responses to disruptive stimuli (i.e., those resulting in eyrie failure and site abandonment) are very difficult to link with any certainty to the causative factor. In hopes of identifying any clear trends, however, we visited the test eyries late in the season and reported the number of young fledged or near fledging (if a breeding effort was underway and if the young were not already near fledging at the time of the stimulus) and in 1981 we briefly visited all eyries tested in 1980 to determine site reoccupancy rates.

RESULTS AND DISCUSSION

LONG TERM EFFECTS

Productivity (rates at which young fledge) and reoccupancy (rates at which test eyries are occupied in the year(s) following testing) are good measures of the long term effects of the test stimuli on breeding raptors. In birds of prey it is normal for a fair share of the breeding population to fail to produce young (see discussion in Newton 1979: 128-149). In 55 Arizona Peregrine Falcon breeding attempts since 1976 where the outcome was clearly known, 33 (60%) fledged young (Ellis and Grubb Unpubl. 1981). Almost all of the test sites of all species fledged young in 1980 and 1981. Reproductive outcome and site reoccupancy rates are reported on an eyrie by eyrie basis for the 1980 eyries in Table 7. Productivity rates for the 1981 eyries are reported in the figures accompanying the species accounts of this section. Although we could not determine if the birds which returned to each eyrie were the same individuals present in 1980, we can say that the reoccupancy rates for all eyries was very high. Only one site was apparently not reoccupied in 1981 by the same species tested in 1980. Even in our brief 1981 visits we were able to determine that reproductive efforts were underway at 16 of 19 eyries.

HEART RATE EXPERIMENTS

Heart rate (HR) even of resting (incubating) falcons proved highly variable. In the male falcon resting HR, averaged over a 2.5 minute interval, varied from 168 to 200 bpm ($\bar{x}$ = 191, N=7). Representative data tracks are presented in Figure 5 for various experimental and natural situations. Each data point represents the average rate for the preceeding four beats: aberrant points are considered artifacts due to either extraneous vibrations (such as shuffling of the adult's feet or radio interference). Note that for any 2.5 minute block the HR typically varies over a 25-30 bpm range even for the most compact data tracks. Long term gradual changes in average rate were also evident in the data complicating the interpretation of the stimulus-response sequences. For example, if the pre-stimulus HR was very low, it was sometimes 20 minutes or more before the post-stimulus HR again dropped to this level although the post-stimulus HR might quickly reach a lower asymptote well below the maximum resting HR for the individual falcon.

In Tables 8 and 9 heart rate data are presented for those stimulus-response bouts where the HR track was clear enough to identify trends. Perhaps the most significant values in the tables are those which report the peak HR values immediately post stimuli and the time until the lower asymptote in HR is achieved after a stimulus. These values can be compared with similar parameters for a natural situation, a falcon alighting and settling to incubate, in Table 10. From the tables, alighting HRs are typically as elevated as the most elevated post stimulus HRs. The time

TABLE 7

PRODUCTIVITY AND REOCCUPANCY OF SITES TESTED IN 1980[1]

Species	Site	1980 Stimulus Situation No. jets : No. booms	1980 Nesting Success[2]	1981 Reoccupancy by Same Species: Present	1981 Reoccupancy by Same Species: Nesting
Cooper's Hawk	1	32 : 1	+	+	+
Black Hawk	1	0 : 2	+	+	+
	2	10 : 0	+	+	+
	3	7 : 0	+	+	+
Zone-tailed Hawk	1	32 : 1	+	+	+
	2	32 : 0	+	+	+
Red-tailed Hawk	1	14 : 0	+	+	+
	2	8 : 0	+	+	Unknown[3]
	3	8 : 2	+	+	+
	4	16 : 1	+	+	Unknown[3]
Golden Eagle	1	3 : 1	+	+	+
Prairie Falcon	1	2 : 1	+	+	+
	4	16 : 3	+	+	+
	10	14 : 1	–	–[4]	–
	11	19 : 4	+	+	+
Peregrine Falcon	3	4 : 0	+	+	+
	4	5 : 1	+	+	+
	5	10 : 2	+	+	+
	6	6 : 0	+	+	+
Totals	19	N.A.	18 (of 19)	18 (of 19)	≥16 (of 19)

[1] Only those sites are included which received >1 test stimulus.

[2] Sites were considered successful (+) if one or more young were fledged (or reared to near fledging if a post-fledging visit was not made).

[3] Only one bird seen on brief visit.

[4] Site occupied by Red-tailed Hawks in 1981.

FIGURE 5

HEART RATE TRACKS FOR SELECTED EVENTS AT PRAIRIE FALCON SITE 11:81

A. Female Settles to Incubate: 1 Apr 15:02

B. Female Response to Propane Cannon: 9 Apr beginning at 17:52

C. Female Responds to 8 A-7 Passes: 31 Mar 15:57

D. Female Responds to a Nighttime Mortar: 15 Apr 03:23

E. Extreme Female Response to a Mortar: 22 Apr 17:33

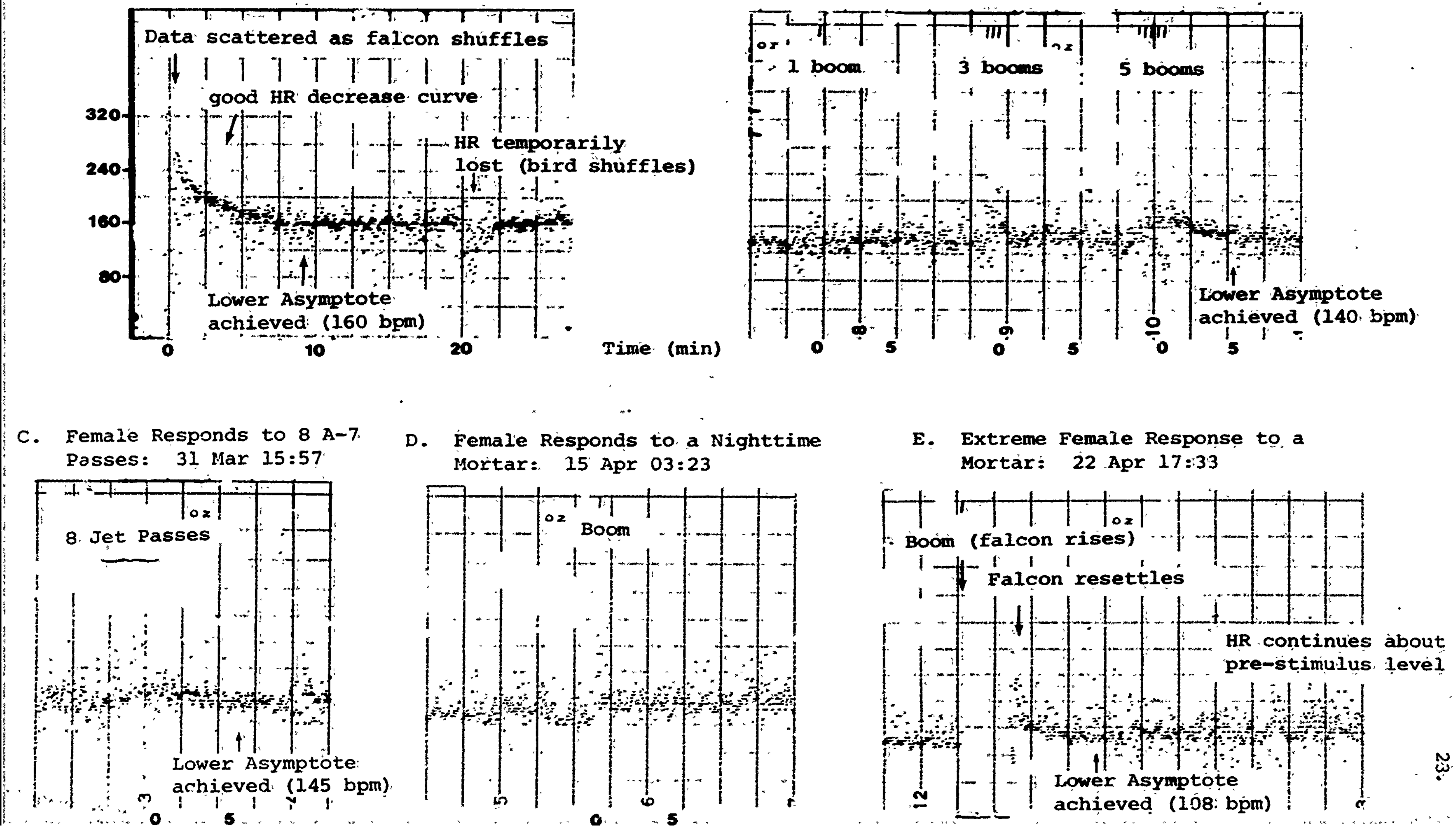


TABLE 8

HEART RATE RESPONSES OF INCUBATING PRAIRIE FALCONS[1] SUBJECT TO MILITARY JETS

Date	Time	Sex	Stimulus	Heart Rate Parameters: Pre-Stim Rate[2]	Post-Stim Peak[3]	5 min Rate[4]	Time Ret[5]	Rate Asym[6]	Time Asym[7]	Evaluation[8]
31 Mar	09:45	M	2 loud distant jets	160	178	175	5	168	6	Short term Minor change
31 Mar	12:44	F	A-10, 2 passes: 80-250 m horiz, 0-50 m up	168	168	168	0	168	0	No change
31 Mar	15:17	F	A-7, 7 passes: high overhead	180	180	180	0	180	0	No change
31 Mar	15:57	F	A-7, 8 passes: 100-250 m horiz, 0-100 m up	145	164	152	5	145	6	Short term Minor change
14 Apr	15:12	F	A-10, 4 passes: 100-150 m horiz, 0-50 m up	188	arose	176	5	172	<8	Falcon arose
22 Apr	08:39	F	F-4, 9 passes: high	124	arose	158	35	152	3	Falcon arose
22 Apr	13:35	F	F-4, 2 passes, high but loud	180	180	172	0	172	5	No change
22 Apr	14:01	F	F-4, 1 pass: high but very loud	172	172	172	0	172	0	No change
23 Apr	11:38	M	A-10, 2 passes: 500 m overhead	224	220	216	0	216	4	No change
23 Apr	13:29	F	jets, 8 loud passes	128	160-180	124	2	120	3	Minor change after 1st & 2nd passes
23 Apr	16:36	F	A-7, 4 passes: 60-90 m horiz, at eyrie level	132	160	140	3	132	4	Minor change

1 Prairie Falcon site 11:81.

2 Pre-Stim Rate: Pre-stimulus heart rate. Resting HR for the male was 168-200 ppm ($\bar{x}$=191,N=7): for the female, 132-185 ppm ($\bar{x}$=150,N=19).

3 Post-Stim Peak: Post stimulus heart rate peak. Because the data display is not a continuous line, the value reported here is an approximate average rate for the 0.5 minute following the stimulus. Higher instantaneous peak rates are evidenced in the scatter pattern.

4 5 min Rate. Heart rate at 5 minutes after stimulus.

5 Time Ret: Time from stimulus until the heart rate returns to the pre-stimulus rate. Heart rate naturally fluctuates widely and when a pre-stimulus rate was very low, it sometimes was not encountered again for an extended period even-though the heart rate leveled off at a normal level, hence the post-stimulus lower asymptote is also treated in the table.

6 Rate Asym: Post-stimulus asymptote, the lower asymptote of heart rate values approached after the stimulus

7 Time Asym: Time from the stimulus until the post-stimulus HR asymptote is achieved.

8 When falcons were most disturbed they arose leaving no immediate HR record.

TABLE 9

HEART RATE RECORDS OF INCUBATING PRAIRIE FALCONS SUBJECTED TO SIMULATED SONIC BOOMS[1]

Date	Time	Sex	Stimulus[2]	Heart Rate Parameters[3]: Pre-Stim Rate	Post-Stim Peak	5 min Rate	Time Ret	Rate Asym	Time Asym	Evaluation
9 Apr	12:55	F	3 propane cannon booms	168	F readjust position & signal temp-orarily lost	152	0.5	152	5	Minor change or none
9 Apr	13:22	F	1 propane cannon boom	152	152	144	0	144	4	No change
9 Apr	13:48	F	1 propane cannon boom	140	164	144	ca 7	140	7	Minor change
9 Apr	17:52	F	1 propane cannon boom	140	140–160	140	0:10	140	0	Minor change or none
9 Apr	18:03	F	3 propane cannon booms in ca 1 minute	140	ca 168	148	ca 6	144	2	Minor change
9 Apr	18:14	F	5 propane cannon booms in ca 2 minutes	140	ca 180	140	ca 5	140	6	Moderate change
9 Apr	19:14	F	7 propane cannon booms in 2.5 minutes	104	140	ca 112	signal lost at 4 min.	112	4	Moderate change
15 Apr	03:23	F	1 mortar salute	136	160	152	30	152	3	Minor change
16 Apr	14:58	F	1 mortar salute	132	125	136	0	132	8	No change
22 Apr	12:01	M	1 mortar salute	ca 192	Arose, flew. Resettled in 4 min.	--	ca 8–10 min HR 150	140	18	Heart rate drops upon resettling
22 Apr	17:33	F	1 mortar salute	104	Arose & stood in en-trance 3 min	120	32	108	8	Moderate change

[1] Prairie Falcon Site 11:81.

[2] All booms generated at 300 m from nest hole

[3] See footnotes for Table 8 for explanation of column heads.

TABLE 10

HEART RATE CHANGES FOLLOWING ALIGHTING FROM FLIGHT AND SETTLING TO INCUBATE IN PRAIRIE FALCONS[1]

			Heart Rate Parameters[2]				
Date	Time	Sex	Initial Rate[3]	5 min Rate	Rate Asym	Time Asym[4]	Difference: Initial Rate minus Rate asym
31 Mar	09:28	M	200	164	156	5.5	44
1 Apr	15:02	F	240	174	160	9	80
9 Apr	12:25	F	240	192	176	15	64
23 Apr	13:10	F	176	148	132	8	44

1 Prairie Falcon Site 11:81.

2 See footnotes for Table 8 for explanation of column headings.

3 Intial Rate: time of earliest heart rate reading when falcon begins to settle.

4 Time Asym: time from Initial Rate until heart rate levels at an approximate lower asymptote.

required for the falcon to reachieve a resting HR was likewise shorter (usually 3-8 minutes) following the subject stimuli than following flight (5-15 minutes).

The data show that HR alterations for the subject stimuli are well within the range of normal HR responses represented by the HR changes associated with alighting from flight. For several of the stimulus bouts there were no identifiable increases (some sequences even show slight decreases) in heart rate.

CAPTIVE FALCON EXPERIMENTS

Tables 11-14 present data on response levels for the two Austral Peregrine Falcons. The most extreme response occurred on 13 August when the male attempted to fly during the third in a series of 6 low level passes. Unfortunately it is not certain that the male was responding to the jet or merely bating (jerking at the end of his leash) as captive falcons often do. In all other episodes response levels were insignificant. These falcons, which had no prior experience with low level jets and minimal experience with loud booms, responded much like wild birds (see stimulus-response records in the Appendices) observed in the study. The intervals between stimulus and first relaxed behavior were of short duration.

Some of the female's responses to extreme stimuli were remarkable. For example, the female circled below (sometimes within 60 m) of approaching jet aircraft and on several occasions, with no apparent hesitation, she pursued and even captured prey as the aircraft swept overhead. These observations,together with the extreme brevity of the post-stimulus interruptions following extreme booms (estimated 148 dB), suggest that the subject stimuli were not unduly alarming to these falcons.

SPECIES ACCOUNTS

In this section generalizations are made from the stimulus-response episodes detailed in the Appendices. In addition, the frequency and timing of the study stimuli and nesting success are presented graphically (Figures 6-9) on an eyrie by eyrie basis. The species are presented in the phylogenetic sequence followed by Brown and Amadon (1968).

1. Bald Eagle (Haliaeetus leucocephalus). Because low level jets were occasionally observed in the vicinity of two reproductively unsuccessful Bald Eagle nests in the southwest (U.S. Forest Service unpubl. field notes), we planned to test several pairs of the nonendangered northern race (H. l. leucocephalus) nesting on the Chippewa National Forest in Minnesota. Unfortunately Forest Service support for the project was withdrawn for political reasons and eventually the Fish and Wildlife Service declined to issue permits even though the study was instigated at Fish and Wildlife Service insistance and low level jet operations are a continuing phenomenon on the proposed study area.

TABLE 11

RESPONSES OF MALE AUSTRAL PEREGRINE FALCON TO LOW LEVEL A-10 JET PASSES

Date	No. Passes	Vertical Distance to Craft[1]	Behavioral Record	Time Until First Relaxed Behavior	Evaluation
12 Aug	6	120-150 m	Watch 4 passes, sleeked & watch last 2	0:30 fluff	Alert-Alarm
13 Aug	6	100-150 m	Sleeked, watches 2 passes: bates (i.e., attempts to fly) on 3rd.	0:32 fluff	Alert-Flush
17 Aug	12	100-170 m	Watches early passes without sleeking, elevates wings on 5th pass. Mostly ignores #6-12. (Although tethered) bates toward & tries to capture pigeon released for female under 9th.	Relaxed throughout	Alert-Ignore
18 Aug	3	130 m	Watch each pass. Little or no sign of alarm.	No identifiable interruption	Alert
20 Aug	8	130-170 m	Jumps (startled) on 1st pass, watches 2nd & 3rd, bates toward pigeon on 4th, ignores 5th, shows flight intention movements (in response to pigeon?) below 6th & 7th passes, ruffle-shakes below 8th.	Startled briefly below 1st pass	Alarm-Ignore

1 All passes were overhead or nearly so, hence no horizontal component is reported here.

TABLE 12

RESPONSES OF FEMALE AUSTRAL PEREGRINE FALCON TO LOW LEVEL A-10 JET PASSES

Date	No. Passes	Vertical Distance to Craft[1]	Behavioral Record	Time Until First Relaxed Behavior	Evaluation
13 Aug	6	100-150 m	Sleeked watches 2 passes, cast off after 2nd pass, circles below 3rd & 4th passes, remains perched on hillside below 5th & 6th passes.	Relaxed after last pass. Never significantly disturbed.	Alarm-Alert
17 Aug	12	100-170 m	Watch sleeked & fluffed 4 passes, then launched & circled below 5th pass. Perches below 6th. Stoops on pigeon below #7, circle below #8, stoops on pigeon below #9 & lands near pigeon & perches below #10. Picked up below pass #11. Circles below pass #12 & stoops & takes pigeon 5 sec. after #12.	Never significantly disturbed	Alert & Ignore
18 Aug	3	130 m	Falcon feeding, interrupts meal 8 sec on 1st pass, 2 sec on 2nd & 6 sec on 3rd.	Feeding 8, 2 & 6 sec. after passes	Alert
20 Aug	8	130-170 m	Soars as craft approach & circles 70 m below 1st pass, stoops at pigeons on 2nd & 3rd passes. Hits a sealed pigeon twice & binds to it as pas #4 approaches. Out of sight on ground with pigeon on remaining passes.	No identifiable interruption	Ignore

[1] All passes were overhead or nearly so, hence no horizontal component is reported here.

TABLE 13

RESPONSES OF MALE AUSTRAL PEREGRINE FALCON TO PROPANE CANNON BLASTS[1]

Date	Time of Boom (hr:min:sec)	Pre-Stimulus Behavior	Response	Time Unit First Relaxed Behavior (min:sec)	Evaluation
12	17:54:20	Perched	Wings immediately lifted in flight intention movement, head high & rapid side to side looking	0:12 look down 0:20 foot watch	Alarm
	17:55:16	Perched	Lurch & look around	0:09 chin fluff	Alert
13	18:35:53	Feeding since 18:29	Flaps 3 time & sleeks	0:07 tear prey	Alarm
	18:38:25	As above	Sleeks & looks about rapidly	0:03 tear prey	Alarm
	18:40:30	As above	As above	0:16 tear prey	Alarm
	18:42:13	As above	Stops feeding & looks about	0:32 tear prey	Alert
18	17:26:03	Perched	Head up, look around	0:37 fluffed	Alert
20	18:31:33	Feeding since 18:30	Lurch, look up & quickly re-resume meal	0:04 tear prey	Alert
	18:33:29	As above	Lurch & look about briefly	0:02 tear prey	Alert

[1] All blasts were for cannon 13 m distant and directed 5-15° away from the falcon. All tests were in August 1981. Action pattern names are after Ellis (1979).

TABLE 14

RESPONSES OF FEMALE AUSTRAL PEREGRINE FALCON TO PROPANE CANNON BLASTS[1]

Date	Time of Boom (hr:min:sec)	Pre-Stimulus Behavior	Response	Time Until First Relaxed Behavior (min:sec)	Evaluation
13	18:35:53	Perched	Sleeks & looks about	0:23 headbob	Alarm
	18:38:25	Perched	Sleeks & looks about	ca 0:05 fluff	Alert
	18:40:30	Perched	Looks about rapidly: response less than for second boom	0:16 defecate 0:20 scratch	Alert
	18:43:13	One-leg-stand	Lowers second leg & watches	0:32 fluff	Alert
16	17:26:03	Perched	Looks rapidly abolt	0:05 tailshake	Alert
20	18:31:33	Feeding since 18:15	Lurch, look up & quickly resume meal	0:03 pluck	Alert
	18:33:29	Feeding since 18:15	Lurch slightly, look up & quickly resume meal	0:01 tear	Alert

1 All blasts were for cannon 13 m distant and directed 5-15° away from the falcon. All tests were in August 1981. Action pattern names are after Ellis (1979).

Although we made no direct observations of Bald Eagle responses, there are some published references to Bald Eagle behavior which may have bearing. First, it became known from the 1971 U.S. Senate hearings on predator control (U.S. Senate 1971) that Bald Eagles are much more difficult to approach (and shoot) from a helicopter than are Golden Eagles (Aquila chrysaetos). Second, Bald Eagles are much more aggressive than Golden Eagles at the eyrie (pers. observation). Grubb (1976) incurred a Bald Eagle attack when scaling a nest tree in Alaska. White and Sherrod (1973 and pers. comm.) report that Bald Eagles will sometimes even attack aircraft near the nest.

There are some unpublished observations of Bald Eagles nesting in close proximity to stimuli like that used in the study. I am informed that Bald Eagles nest very near an actively used gunnery target subject to F-4 Phantom aircraft straffing runs at McDill Air Force Base, Tampa, Florida (pers. comm. David Kleintz, USFWS, Houston, Texas: also contact Captain John Shirtz, Environmental Office, McDill AFB). Bald Eagles (1-2 pair) nest near artillery ranges on the Aberdeen Proving Ground, Maryland. In 1980 a pair successfully fledged one young from a nest within 200 m to the side of the projectile path and midway between the artillery firing position and the impact zone (pers. comm. William S. Clark, Director, Raptor Information Center, National Wildlife Federation, Washington, D.C.: also contact William Russell, Environmental Management Office, Aberdeen Proving Grounds, Maryland). It would be useful to observe the responses of these birds during straffing runs and artillery practice. Without these observations little else can be said.

2. Cooper's Hawk (Accipiter cooperii). In the few tests performed on this species (Figure 6), the adult female and large young responded minimally to jet aircraft only 100 m overhead.

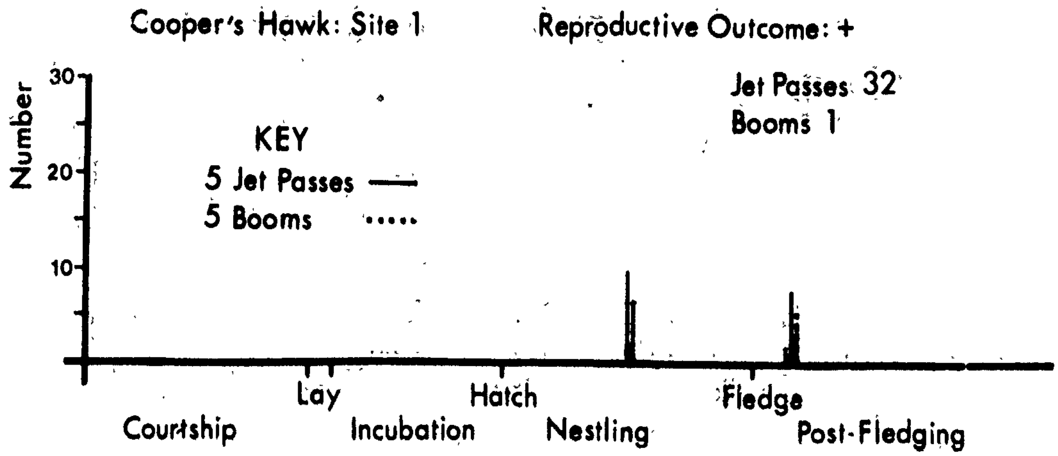
3. Black Hawk (Buteogallus anthracinus). The test stimuli are displayed in Figure 6. The experiments summarized in the Appendices largely resulted in alerting the adult and young. On one extremely close pass (100 m overhead) a fledgling crouched (cowered) for a short period.

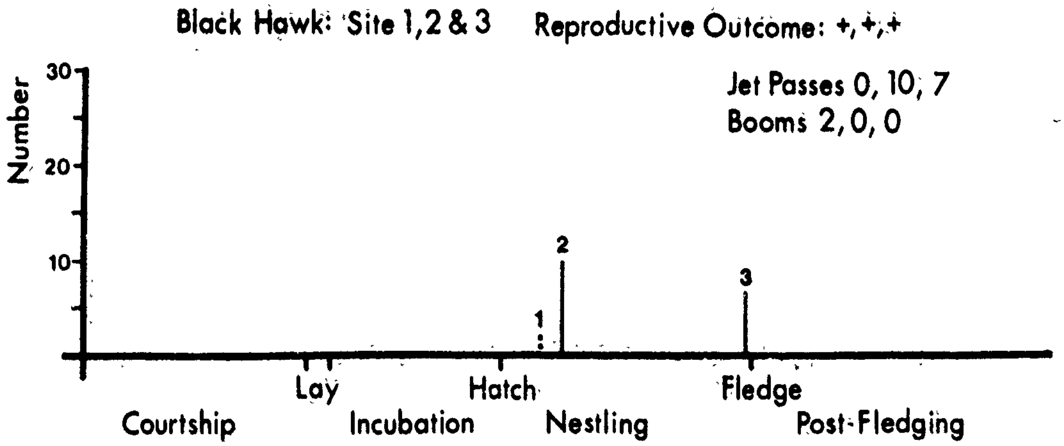
4. Harris' Hawk (Parabuteo unicinctus). Interpretation of the few data obtained for this species (Figure 6) is complicated by the fact that the adults were already disturbed by a nearby observer in full view. The Harris' Hawk nests over much of the Sells MOA where sonic booms and low level jets are frequent. Although it is unlikely that wild Harris' Hawk responses to real sonic booms are as significantly negative as those observed in this study (adults sometimes fled), the situation deserves further inspection.

5. Zone-tailed Hawk (Buteo albonotatus). In response to multiple passes (Figure 7) adults and young most often were only alerted even when the aircraft were very low (100 m). Once the adult female continued feeding chicks when A-10 aircraft passed within 150 m. Each site fledged two young. On the first pass, one day late in the season, the adult female and one nestling crouched briefly as two craft passed over. Nestling responses to the only test boom were minimal.

FIGURE 6

STIMULUS LEVELS AT SELECTED RAPTOR NEST SITES: COOPER'S HAWK, BLACK HAWK, AND HARRIS' HAWK





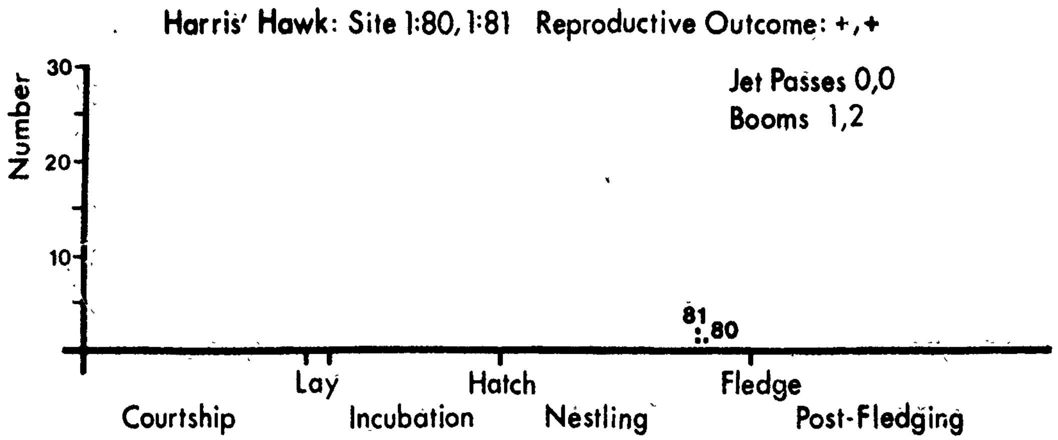
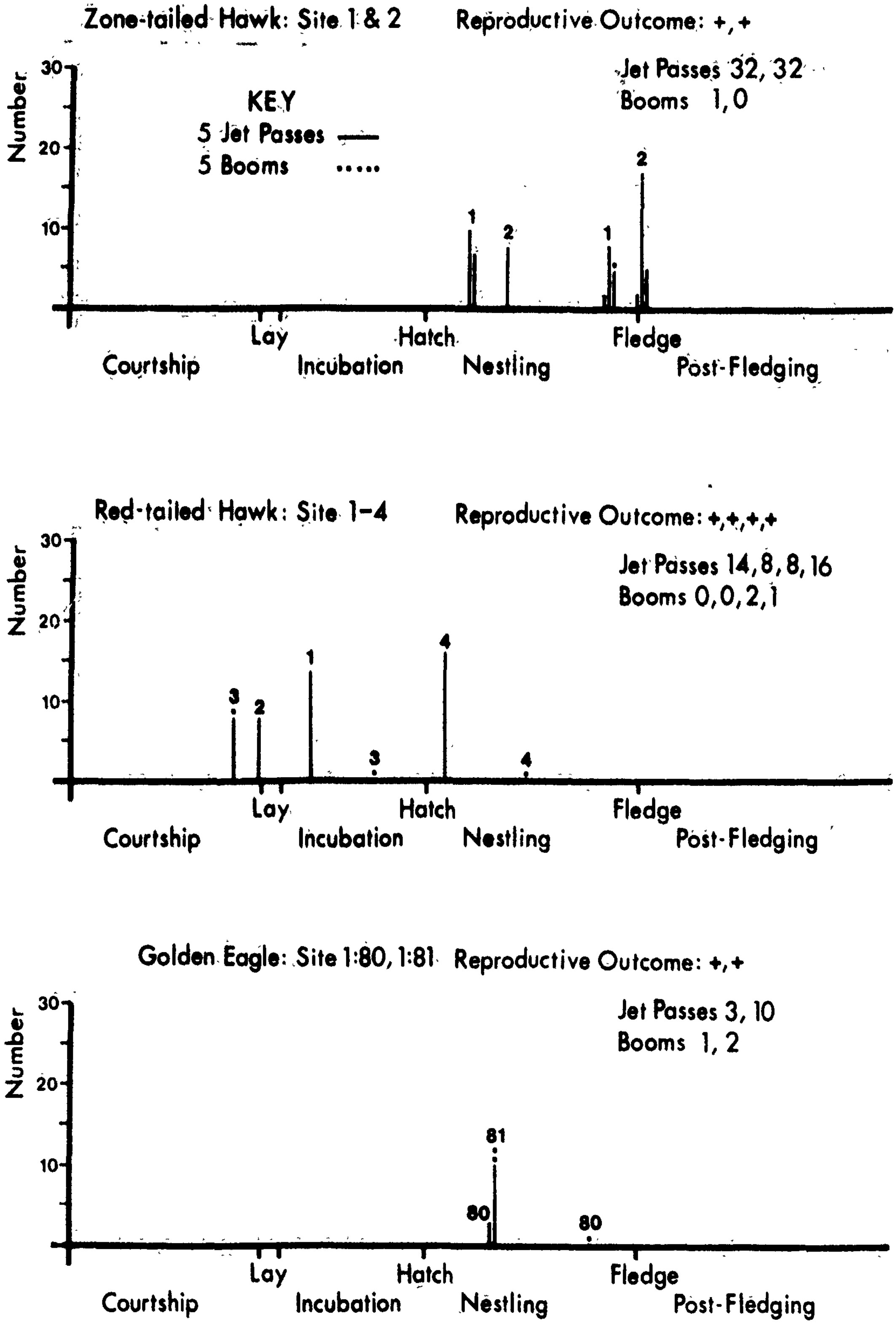


FIGURE 7

STIMULUS LEVELS AT SELECTED RAPTOR NEST SITES:
ZONE-TAILED HAWK, RED-TAILED HAWK AND GOLDEN EAGLE



6. Red-tailed Hawk (Buteo jamaicensis). The timing of the test stimuli is presented in Figure 7. This species proved incredibly tolerant to low level jet traffic. Once an adult flew toward two approaching A-10 aircraft (150 m overhead) and entered the nest. Even more remarkable an adult female responded to the approach of four A-7 aircraft by reaching into the nest and swallowing the remains of a Kangaroo Rat (Dipodomys sp.).

Considering how tolerant were Red-tailed Hawks of nearby jets, it was doubly surprising how significantly they responded to booms, more so than any other species. In two cases the rockets and observers were visible to the birds which could account in part for the degree of alarm shown, but in the third instance (Site 4 in Appendix II) the adult female interrupted a feeding bout and lept out of the nest on the explosion even though the rocket was hidden by the cliff and the observer was well concealed in a blind which the birds had long since learned to disregard. It would be interesting to see the outcome of many more boom trials with this species, although the relative abundance of nesting Red-tailed Hawks on the Sells MOA and Luke Air Range, where sonic booms are very common, make it unlikely that productivity limiting responses are exhibited by the adults, indeed, all of our experimental pairs nested in these areas and all fledged young.

7. Golden Eagle (Aquila chrysaetos). Golden Eagles are especially sensitive to humans near their nests (Ellis 1979). From the few data gathered in this study (Figure 7) it is not possible to be certain if this sensitivity is also reflected in a greater sensitivity to sonic booms and low level jets. In 1980 two Golden Eagle eyries were located along a heavily used low level jet corridor. Both fledged young. Golden eagles are also frequently observed in the desert mountains of the Fort Luke Air Range where sonic booms and low level jets are regular.

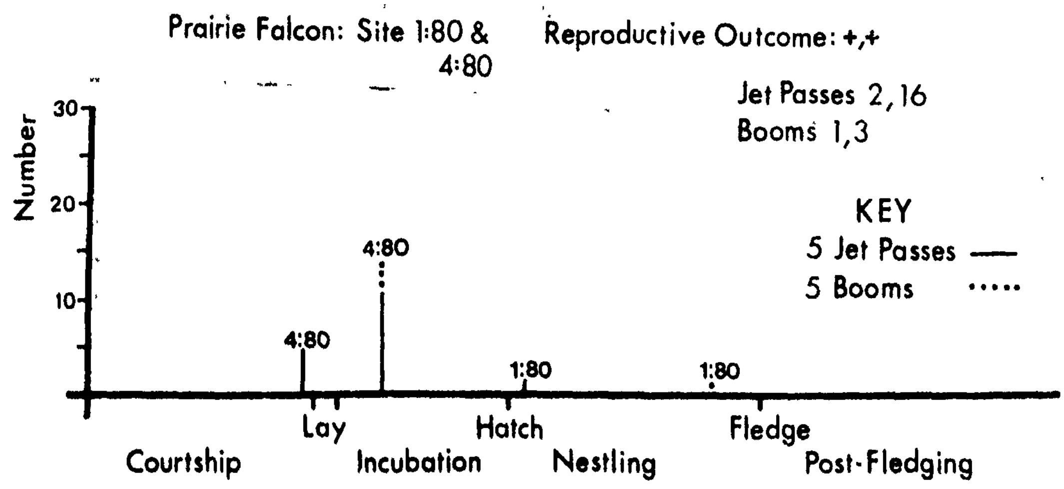
At a Golden Eagle eyrie in Montana (April 1971) I observed responses of the adult female during an electrical storm. The bird was alarmed by nearby lightening and thunder but ignored loud thunder claps when lightening was not visible.

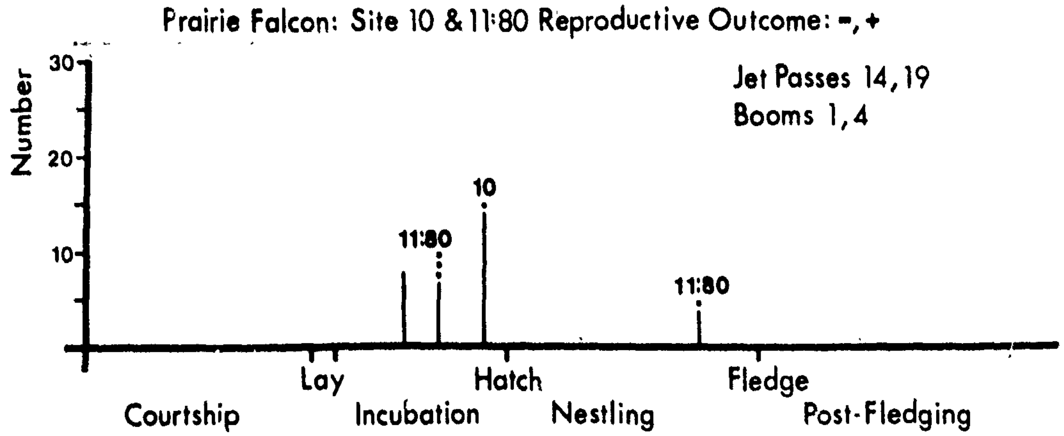
In this study one large nestling responded to an extreme boom (estimated 141 dB) by cowering momentarily. It was not possible to be certain if the adult which fled following a propane cannon blast was responding to the blast alone or synergistically to the presence of an observer and the cannon blast.

8. Prairie Falcon (Falco mexicanus). In Figure 8 the timing of the stimuli is displayed. Responses were highly variable for this species (Table 15). Occasioally adults flew out and circled in response to repeated jet passes and booms. There were three observatios of fleeing behavior. An adult female during courtship (Site 4:80) twice fled as low level jets,which were first visible from a great distance, continued directly toward her. Once a nonproductive adult (Site 7), late in the season, left the cliff and disappeared across the desert after the last of three booms (with the observer visible). Most often the falcons were merely alerted or alarmed even by the extreme test stimuli incurred in

FIGURE 8

STIMULUS LEVELS AT SELECTED PRAIRIE FALCON EYRIES





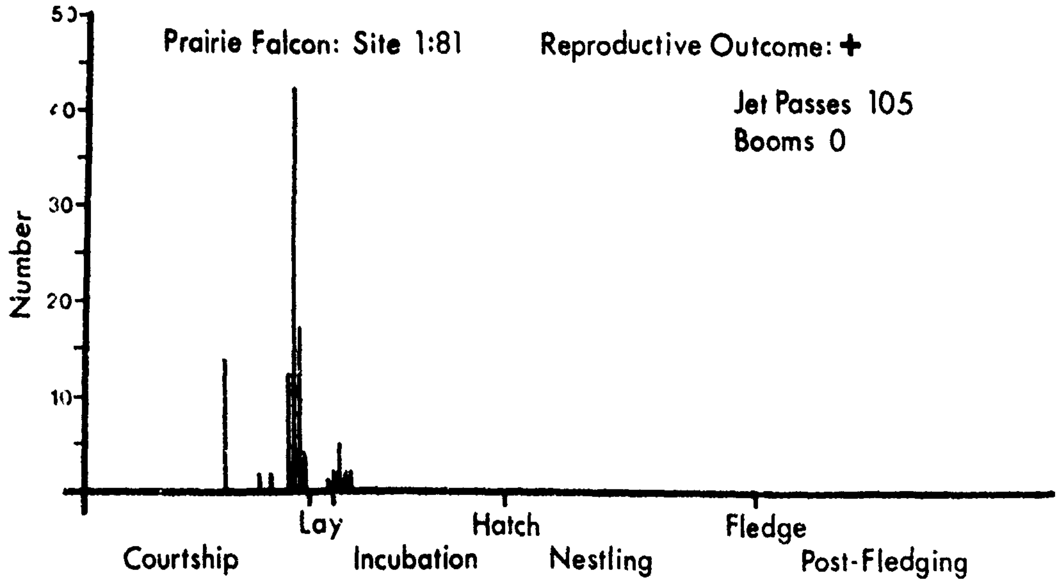
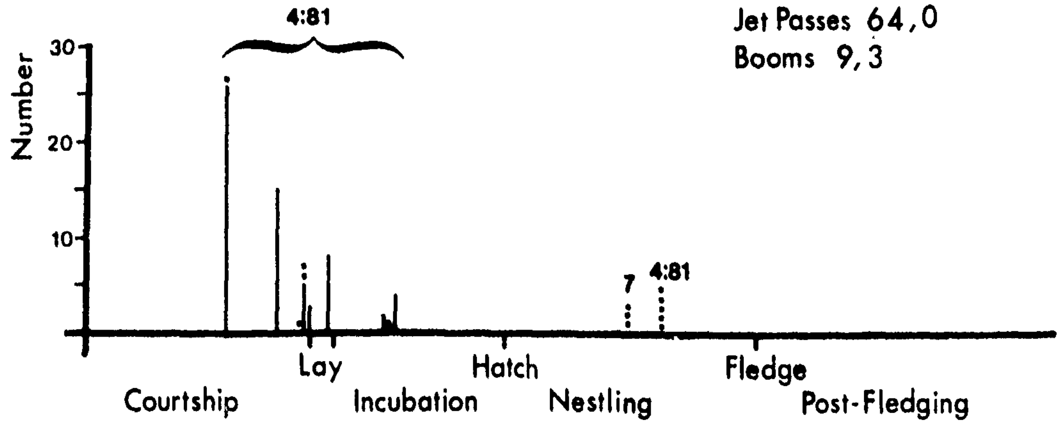


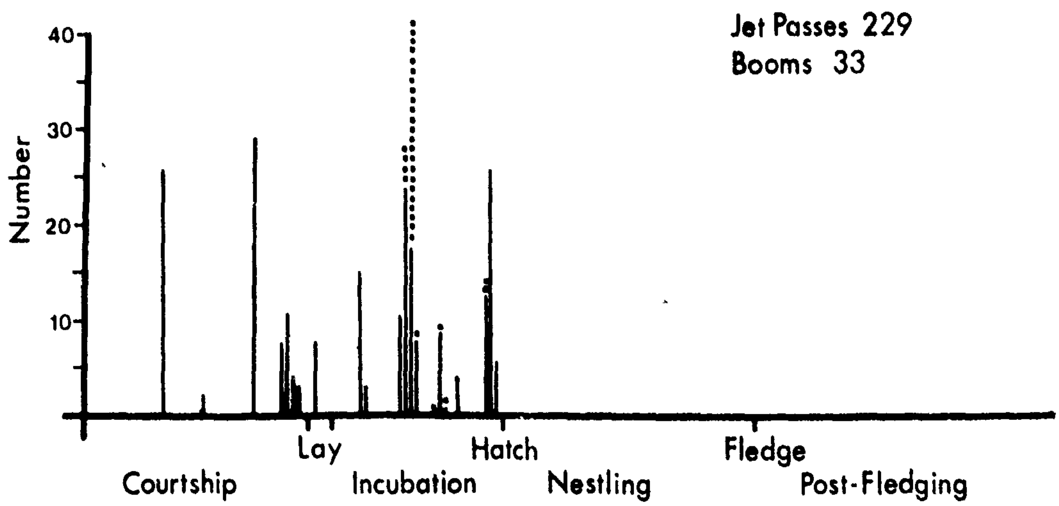
FIGURE 8 (cont.)

STIMULUS LEVELS AT SELECTED PRAIRIE FALCON EYRIES

Prairie Falcon: Site 4:81 & 7 Reproductive Outcome: +, N/A



Prairie Falcon: Site 11:81 Reproductive Outcome: +



Prairie Falcon: Site 12 Reproductive Outcome: +

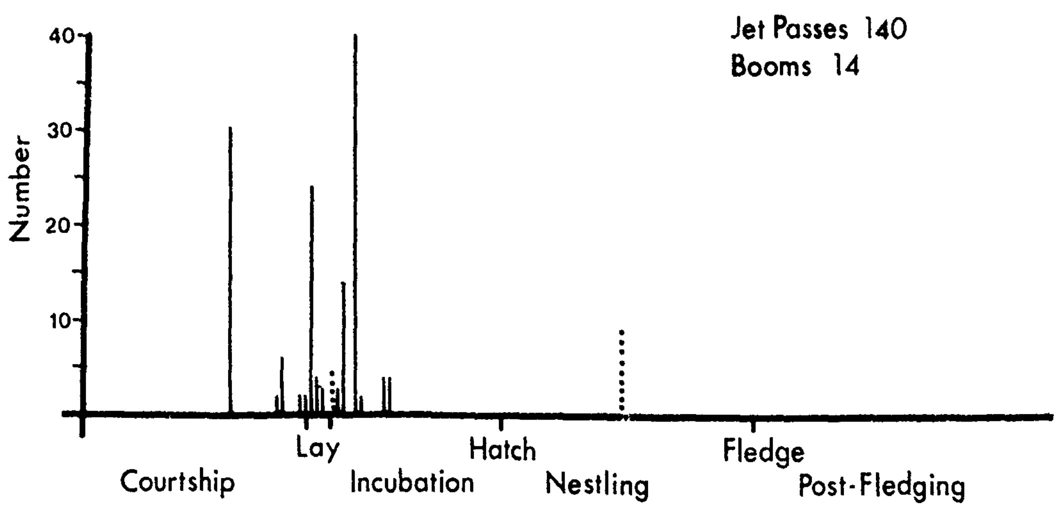


TABLE 15

SUMMARY OF ADULT PRAIRIE FALCON RESPONSE LEVELS TO NEARBY JETS AND BOOMS[1]

Stimulus	Response Classes: Number (Percentage)							Total
	Ignore	Alert	Alarm	Call	Flies Out	Flees	Abandon Site	
Jets	22 (29)	38 (49)	9 (12)	1 (1)	5 (6)	2 (3)	0 (0)	77
Booms	4 (11)	20 (54)	8 (22)	0 (0)	4 (11)	1 (3)	0 (0)	37

[1] Because of extreme variability between stimulus situations, stages of the nesting cycle, etc., the episodes, although tabulated here, should be compared only with great caution.

this study. It is perhaps significant that in Table 15 low level jets less often caused alarm than did booms. I interpret this situation as follows: the falcon sees the jet approaching, evaluates the danger, and responds without alarm, whereas for a sudden boom, the falcon has no early warning and as a result sleeks and looks rapidly about while assessing the danger.

It is noteworthy that even when adults did leave the eyrie they did not burst forth and thereby endanger eggs or small young as observed by White and Sherrod (1973) and Cade (1960). Incubating adults seldom rose even with the most alarming stimuli. On the few occasions when they did exit, they walked to the eyrie lip, then launched. As was noted earlier, however, one of the original three eggs at Site 11:80, where we conducted our heart rate experiments, was found broken in the eyrie on our last visit just before hatching.

As for the Peregrine Falcon treated next, young Prairie Falcons fled deep into the eyrie in response to alarming stimuli.

9. Peregrine Falcon (<u>Falco peregrinus anatum</u>). Stimulus levels for this species are reported in Figure 9. Because of the ruggedness of the areas where this species breeds (e.g., average cliff height at recent Arizona eyries is 475 feet (145 m): Ellis under review), we obtained direct observations of adult responses in the eyries at only four sites. More often we observed the responses of adults and young while they perched on the breeding cliff or flew in the area. Still more frequently, we observed jets and saw no birds at all.

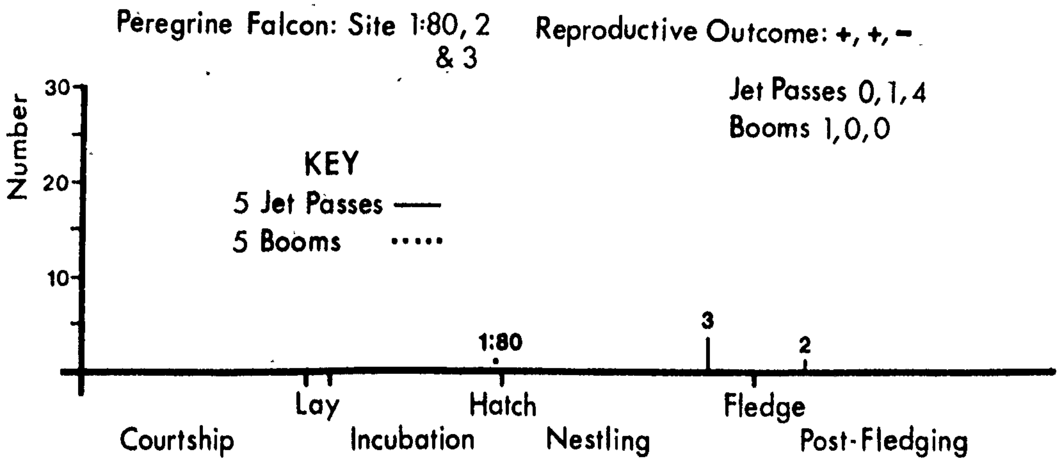
We obtained several observations of Peregrine Falcons flushing in response to booms. Unfortunately, for most of these episodes, the birds were at the same time at least mildly disturbed by observers in the area.

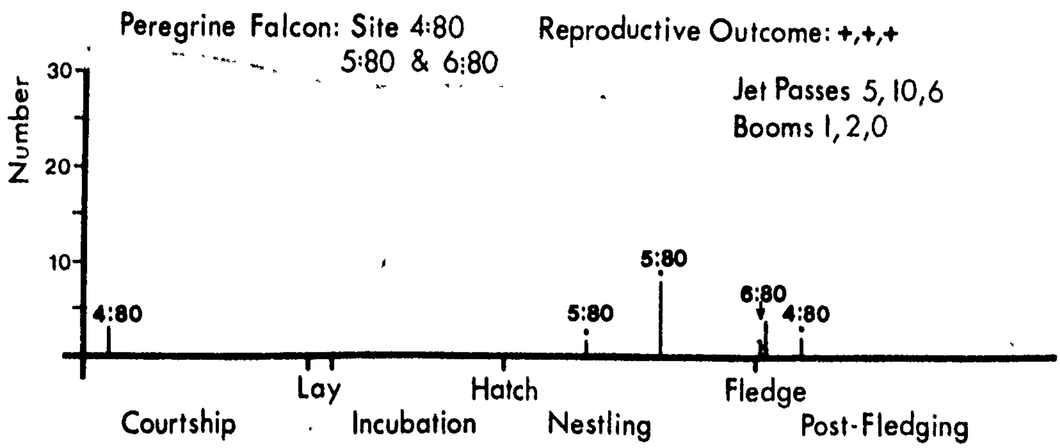
An interesting observation made in the Queen Charlotte Islands, British Colombia, Canada indicates that Peregrine Falcons are moderately annoyed by certain kinds of noise. Wayne Nelson (pers. comm., 1980) observed the incubating adult(s) repeatedly headshake in response to the high pitched foghorn whistle at a nearby lighthouse. A laboratory investigation of the noise tolerances of the falcon for various frequency and energy levels may provide an important management tool in areas where noise generating devices (such as fog horns) are to be installed amid bird of prey habitat.

In general the responses of the Peregrine Falcon to the subject stimuli were like those for the Prairie Falcon. Nestlings responded to nearby jets by fleeing into the eyrie. Two fledged juveniles (Site 6:81) showed no fear or avoidance to jets making repeated passes as they soared together. Adults were typically alerted or alarmed by the stimuli, but peregrines flew out and circled more often than did Prairie Falcons in response to booms. We gathered no evidence of site abandonment or reproductive failures in association with the subject stimuli. All sites tested in 1980 were reoccupied in 1981.

FIGURE 9

STIMULUS LEVELS AT SELECTED PEREGRINE FALCON EYRIES





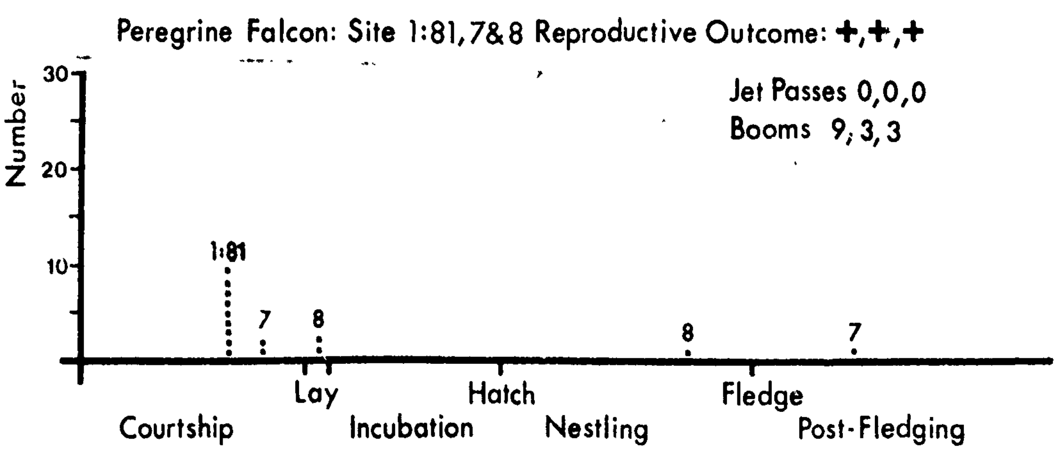
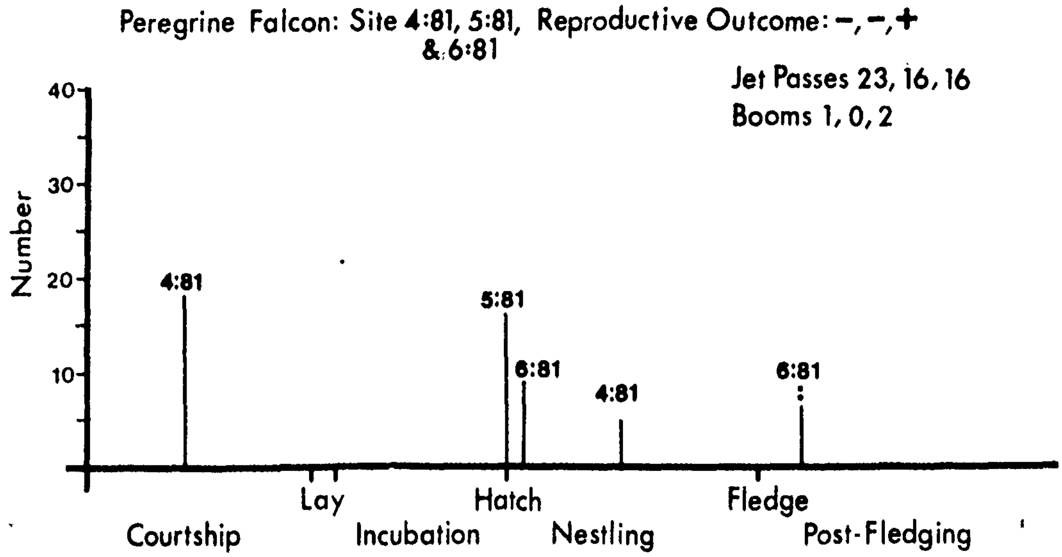
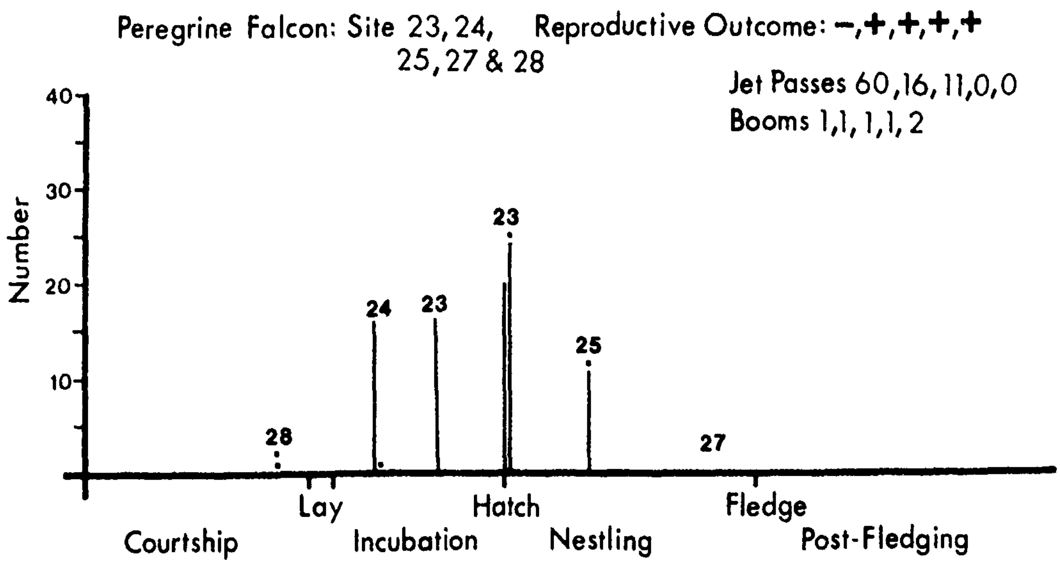


FIGURE 9 (cont.)

STIMULUS LEVELS AT SELECTED PEREGRINE FALCON EYRIES





GENERALIZATIONS ON SHORT TERM BEHAVIORAL RESPONSES

Much variation between birds was observed, however, some broad generalizations are outlined below:

A. Responses to jet aircraft
   1. Small nestlings do not respond noticeably.
   2. Large nestlings in exposed nests (e.g., stick-tree nests) are alerted by and sometimes cower below the closest aircraft (100 m or less).
   3. Large nestlings in cavity nests often flee into the cavity and cower in response to the closest aircraft.
   4. Large nestlings are alerted by distant aircraft (>300 m) but show no alarm.
   5. Adults ignore or casually watch craft >500 m distant.
   6. Adults are alerted or alarmed by craft closer than 300 m. Occasionally adults ignore even the closest craft. Some birds at some times will flee if closely approached.
   7. Adult behavior suggesting that site abandonment was imminent was not observed during the study.
   8. Nestling behavior suggesting that premature fledging was imminent was not observed during the study.

B. Responses to booms
   1. Small nestlings do not respond noticeably.
   2. Large nestlings are alerted or alarmed: less often young cower.
   3. Adults are most often alerted or alarmed by extreme booms. Occasionally adults respond minimally if at all to very loud booms. Occasionally some birds briefly flee in response to loud booms.
   4. Adult behavior indicative of site abandonment was not observed during the study.

SOME CAUTIONARY NOTES

1. The species treated in this study did not respond to the test stimuli in a significantly adverse fashion: other species may. Platt's (1975 in 1977) data for the Gyrfalcon suggest that several pairs of this falcon did not reoccupy sites where they were harrassed by a low level helicopter the previous year.

2. The boom generating devices used in this study approximate the maximum overpressures associated with mid and high altitude sonic booms. We have no records for responses to the extreme booms that would be produced by a low level supersonic jet. A supersonic jet near ground level would likely cause extreme reactions in nesting raptors (i.e., adults rushing to depart may kick eggs and young out of the eyrie: adults may abandon a site if low level sonic booms continue on a regular basis).

SUMMARY

For this study, we gathered several kinds of data to determine the likely effects of low level jets and sonic booms on nesting Peregrine Falcons and other raptors. We directly observed responses to worst case stimulus loads: responses to extremely frequent and extremely nearby jet aircraft were often minimal, seldom significant and never associated with reproductive failure. Likewise, responses to real and simulated sonic booms were often minimal and never productivity limiting.

In addition to directly observing behavioral responses, in 1981 we invited jet passes at four Prairie Falcon eyries during courtship and incubation when the adults were most likely to abandon, on an ad libitum basis. All four eyries fledged young. Nesting success and site reoccupancy rates were high for all eyries.

In tests of two relatively naive captive Peregrine Falcons, we failed to detect significantly negative responses. Typically the birds either quickly resumed feeding or other activities within a few seconds following a pass or boom. The female falcon repeatedly made hunting forays as jets swept overhead.

From heart rate (HR) data taken via a telemetering egg during incubation at a wild Prairie Falcon eyrie, we determined that stimulus induced HR alterations were comparable to rate changes of the birds settling to incubate following flight. No significant long term responses were identified. The falcons successfully fledged two young even with the more disruptive activities associated with entering the eyrie three times to position and recover the telemetering eggs.

Significantly, birds of prey of several genera commonly nest in the supersonic miliary operations areas in southern Arizona. In addition, raptor eyries are frequently found at locations where low level jet traffic naturally concentrates. For example, Prairie Falcon Site 11 is directly on the approach path to straffing and bombing targets. Prairie Falcon Site 1 is in a narrow canyon through which A-10 aircraft naturally funnel while flying low altitude tactical navigation (LATN) missions. Both sites successfully fledged young both years of the study.

In summary, while the birds observed for this study were often noticeably alarmed by the subject stimuli, the negative responses were brief and never productivity limiting. In general, the birds were incrediby tolerant of stimulus loads which would likely be unacceptable to humans. It is significant that the endangered species recovery plan for the Peregrine Falcon in the southwest (USFWS 1977) fails to mention military jet operations as a likely factor in the falcon's decrease or that military jet operations should be taken into account in the species recovery.

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APPENDIX I

STIMULUS-RESPONSE SUMMARIES FOR JET PASSES

Species	Site	Date	Time (hr:min)	Stage	Subject	Stimulus	Response	Duration of Interruption (min:sec)	Evaluation
Coop H	1	10 Jun	16:11	M-N	AF, 3 N	A-10, 10 passes: 100 m overhead	AF continues shading young: watch only	0:00 continues shading	Alerted only
		11 Jun	17:02	M-N	AF, 3 N	A-10, 8 passes: 100-200 m overhead	AF continues shading young: watch only	0:00 continues shading	Alerted only
Black H	2	9 Jun	13:09	M-N	AF	A-10, 6 passes: 100-250 m horiz, 100 m up	AF brooding, watch only	Ca 0-12 sec of tense watching	Alerted only
		9 Jun	16:35	M-N	AF	A-10, 4 passes: 200-350 m horiz, 100 m up	AF feeding chick, interrupted meal few sec. as craft passes	Ca 0:05 then resume meal	Alerted only
	3	3 Jul	08:48	L-N	N	A-10, 4 passes: 100-170 m up, all overhead	N intently watches first highest jet: on 2nd pass N crouches & watches pass; on 3 & 4 no crouching, watch only	Ca .5-1 min maximum	Alarmed to 3 passes N crouch on second pass
		3 Jul	09:32	L-N	N	A-10, 3 passes: #1 70 m horiz, 250 m up; #2-3 overhead, 100-150 m up	N watches all passes intently, on 2nd pass Fledgling lowers from 1-leg stand to 2-leg stand	No significant response	Alerted
Zone-t H	1	10 Jun	16:08	E-N	AF, 2N	A-10, 10 passes: 30-100 m horiz, 100 m up	AF feeding chicks: on first pass did not interrupt meal, on passes 2-5 AF looked up thereby interrupting meal 5 sec on each pass.	0:00-0:05 interrupted meal for 4 of 5 passes	Alerted minimally
		11 Jun	14:49	E-N	AF, 2N	A-10, 3 passes: 0-50 m horiz, 70-100 m up	AF shade young and casually watch craft	0:00 no interruption	Alerted minimally
		11 Jun	17:04	E-N	AF, 2N	A-10, 4 passes: 0-30 m horiz, 60-100 m up	AF stand in nest and watch each pass 3-5 sec.	0:03-0:05 watch only	Alerted minimally
		8 Jul	14:08	L-N	AF, 2N	A-10, 2 passes: 0-20 m horiz, 100 m up	AF stops feeding N; AF & N crouch slightly on first passes; all watch as craft pass	0:05 all appear relaxed but meal ended	Alerted & slight crouching
		10 Jul	09:53	L-N	2N	A-10, 5 passes: 0-50 m horiz, 70-150 m up	2N lower (crouch) to lie posture and watch craft pass	0:52 hunger calling 1:57 older N dozes	2Ns crouch & watch
	2	11 Jun	17:03	E-N	2N	A-10, 8 passes: overhead, ca 80 m up	2N remain asleep	0:00 no interruption	No response from sleeping Ns
		9 Jul	09:02	L-N	2N	A-10, 1 pass: 40 m horiz, 150-250 m up	2N inactive, watch craft	0:05 watch until lost to view	Alerted only

APPENDIX I (cont.)

Species	Site	Date	Time (hr:min)	Stage	Subject	Stimulus	Response	Duration of Interruption (min:sec)	Evaluation
		9 Jul	09:51	L-N	2N	A-10, 16 passes: 0-30 m horiz, 100-160 m up	2N inactive, watch craft	0:00-0:05 watch until lost to view	Alerted only
Red-t H	1	27 Mar	14:36	E-I	AF, AM	F-5, 4 passes: 100 m horiz, 300 m up	AF remains on Saguaro perch AM remains on nest incubating	No change noted	No changes in position
		27 Mar	14:43	E-I	AF, AM	A-7, 2 passes: 0-50 m horiz, 130 m up	AF remains on saguaro perch AM remains on nest incubating	No change noted	No changes in postion
		27 Mar	15:50	E-I	1A	A-10, 2 passes: 0-20 m horiz, 120 m up	A incubating out of sight on nest, remains	No change noted	No changes in position
		27 Mar	16:13	E-I	1A	A-10, 2 passes: 50 m horiz, 120 m up	A remains perched on cactus 150 m from nest, returns to nest 16:15	No change noted, then 01:30 fly to nest	No changes in position
		27 Mar	16:32	E-I	1A	A-10, 4 passes: 0-20 m horiz, 150 m up	A remains on nest incubating (largely out of sight)	No change noted	No change in position
	2	27 Mar	14:40	E-I	AF	A-7, 6 passes: 0-400 m horiz, 150 m up	AF remains on nest incubating, head out of sight	No change noted	No change in position
		27 Mar	16:32	E-I	AF	A-10, 2 passes: overhead, 150 m up	AF remains on nest incubating, head out of sight	No change noted	No change in position
	3	12 Mar	13:44	Lay	AF	A-10, 6 passes: overhead, 150 m up	On 1st pass, AF flew toward craft then settled on nest, incubates during other passes	AF begins incubation, no disturbances noted	AF returns to nest
		12 Mar	16:10	Lay	AF	A-10, 2 passes: 30 m horiz, 150 m up	AF incubating without obvious response	0:00 no changes	No changes
	4	18 Mar	08:57	E-N	AF, 3N	A-10, 2 passes: level with eyrie, 60 m out	AF soaring over cliff out of sight at time of pass, lands on cliff 8:45 after pass	AF out of sight	----
		18 Mar	11:08	E-N	AF, 3N	A-10, 4 passes: 60-100 m out, 30-100 m up	AF watches craft approaching then swallows kangaroo rat remains as they near	0:00 no alarm	No alarm
		18 Mar	11:42	E-N	AF, 3N	A-7, 2 passes: 0-20 m out, 60 m up	AF incubating crouches for first craft & 5 sec after, then ca 25 sec after second craft	0:30 rise, incubate	AF crouches (covers)
		18 Mar	13:07	E-N	AF, 3N	A-7, 6 passes: 0-60 m out, 0-60 m up	AF incubating crouches 25 sec after first pass, 8 sec after second pass	0:25 rises from crouch	AF crouches (covers)

APPENDIX I (cont.)

Species	Site	Date	Time (hr:min)	Stage	Subject	Stimulus	Response	Duration of Interruption (min:sec)	Evaluation
G Eagle	1:80	22 Apr	09:08	E-N	2N	A-7, 1 pass: 400 m out at eyrie level	Adults gone, N give no response	No change seen	No alarm
		22 Apr	09:50	E-N	2N	A-7, 2 passes: 100 m out, 30 m up	2N alert but no obvious response	No change seen	No alarm
Prairie F	1:80	17 Apr	12:54	E-N	AM, AF	A-10, 2 passes: 100 m out, 30 m up	AF out of sight incubating, no change; AM perched out of sight on cliff, no change	No changes seen, both adults out of sight	-----
	1:81	26 Feb	12:26	L-C	1A	A-10, 4 passes: 60-130 m horiz, 75 m up	A ignore first pass, watch second	0:04-0:06	Ignore: Alert 1
		10 Mar	12:16		1A	A-10, 1 pass: 120 m horiz, 30 m up	A continues soaring near jet	0:00	Ignore
		10 Mar	15:12		1A	A-10, 2 passes: 160 m horiz, 75 m up	A continues feeding through 3 of 4 passes: pauses 7 sec on 4th pass	0:06 0:07	Ignore 3: Alert 1
	4:80	12 Mar	08:15	L	AF	A-10, 2 passes: 50 m horiz, 100 m up	AF perch eyrie rim, flees, is overtaken by craft, stoops under craft, doubles back, lands on cliff 6 m from eyrie	Transitional behavior, calm within 5 min., preening	AF flees
		12 Mar	09:37	L	AF	A-10, 2 passes: 50 m horiz, 100 m up	AF perched near eyrie, flees ca 5 sec before craft passes, overtaken by craft, stoops under craft, lands on cliff, rapidly calms	Ca 0.5 min. relaxed visage	AF flees
		12 Mar	11:05	Lay	AF	A-10, 1 pass: 150 m horiz, 150 m up	AF incubating, rises partly as craft nears. resettles	0:55 peers into nest relaxed 6:11 resettles to incubate	Rises to flee but remains
		26 Mar	07:25	E-I	AM, AF	A-10, 1 pass: 150 m horiz, 130 m up	AM incubating, and AF perched on cliff. Both relaxed, watch only.	0:00 no changes in behavior	Both As relaxed
		26 Mar	07:48	E-I	AF	A-10, 1 pass: 75 m horiz, 130 m up	AF incubating, continues	No changes observed, head barely visible	No positional changes
		26 Mar	08:42	E-I	AF	A-10, 1 pass: 0-20 m horiz, 70 m up	AF incubating, watch craft calmly	0:00 watch only	AF watch only
		26 Mar	12:12	E-I	AM, AF	A-10, 2 passes: 120 m horiz, 80 m up	AM incubating without change, AF perched, watches craft intently	0:00 AM relaxed 0:44 AF eyerub	AM no response AF alerted

APPENDIX I (cont.)

Species	Site	Date	Time (hr:min)	Stage	Subject	Stimulus	Response	Duration of Interruption (min:sec)	Evaluation
		26 Mar	13:01	E-I	AM, AF & intrud. AF	A-10, 6 passes: 300-450 m horiz, 100 m up	AM, AF and intruding AF in aerial combat, ignore craft	0:00 all As more intent on social interaction	AM, AF & intruding AF ignore craft
	4:81	18 Feb	14:43	E-C	AF	A-10, 2 passes: overhead, 100 m up	AF watch only: remain on cliff	0:00	Alert
		27 Feb	09:48	M-C	AF	A-10, 1 pass: overhead, 80 m up	AF sleeked and crouched 8 sec but remains on cliff	0:08	Alarm
		27 Feb	12:17-12:24	M-C	AM, AF	A-10, 8 passes: 60-150 m horiz, 0-15 m up	AF ignores some, watches some of 6 passes, then both As circle cliff front calling during 2 passes (not known if responding to jets)	0:00-?	Ignore-Alerted then Flying
		27 Feb	12:34	M-C	AM, AF	A-10, 4 passes: 0-150 m horiz, 40 m up	Both As remain on cliff glancing at jets occasionally. Copulation 20 min. after pass	0:00	Ignore-Alert
		4 Mar	09:34	L-C	AF	Distant but loud jet	AF stop preening 20 sec then resume	0:20	Alert
		4 Mar	09:54	L-C	AM, AF	Loud jet, high overhead	AF ignore, AM screams ca 4 sec	0:00-0:04	AF ignore AM alarm
		4 Mar	10:35	L-C	AM, AF	A-10, 1 pass: 60 m horiz, 60 m up	AF interrupts meal 38 sec AM interrupts preen bout 29 sec	0:38 and 0:29	Alert
		4 Mar	12:00	L-C	AF	A-10, 4 passes: 100-170 m horiz, 50-80 m up	AF watched jets pass: looked away 13 and 20 sec after last pass	.5 min	Alert
	10	11 Apr	08:40	I	AF	A-7, 4 passes: 30-60 m horiz, 0-20 m up	AF incubating, watches 3 passes, ignores 4th pass	0:00 relaxed	Relaxed
		11 Apr	09:42	I	AF	F-4, 4 passes: 100 m horiz, 250-300 m up	AF incubating, watches without alarm	0:00 relaxed	Relaxed
		11 Apr	10:04	I	AF	F-4, 2 passes: 0-50 m horiz, 150 m up	AF incubating, watch sleeked	0:00 no changes	Alerted
		11 Apr	10:12	I	AF	F-4, 4 passes: 0-30 m horiz, 150 m up	AF incubating nervously, watch	2:05 relaxed	Alarmed

APPENDIX I (cont.)

Species	Site	Date	Time (hr:min)	Stage	Subject	Stimulus	Response	Duration of Interruption (min:sec)	Evaluation
	11:80	28 Mar	08:51	M-I	AF	A-7, 8 passes: 150-250 m horiz, 200 m up	AF watches craft, relaxed, incubating	0:00 no interruption	Watch only
		3 Apr	11:54	M-I	AM	F-4, 3 passes: 100-200 m horiz, 500 m up	AM incubating, no response determinable	0:00 no interruption	No change
		3 Apr	14:19	M-I	AM, AF	F-104, 4 passes: 400 m horiz, 1000 m up	AM incubating, continues, no response detectable	0:00 no changes, 1:06 AM doze, 1:17 AM fly to eyrie	No interruption detected
		19 May	15:29	L-N	2N	A-7, 4 passes: 150 m horiz, 200 m up	2Ns loafing at eyrie mouth, rush into cavity on 1st pass	2:56 N reappears at eyrie mouth	2N fled into eyrie
	11:81	24 Feb	10:10	E-C	AM, AF	A-10, 4 passes: 0-30 m horiz, 60-100 m up	AM flush on first pass, AF cower then cast 43 sec after last pass	AM?, AF 0:43	AM flushed AF alerted
		24 Feb	12:12	E-C	AF	A-10, 6 passes: 30-200 m horiz, 60-100 m up	AF walked into nest cavity after 2nd pass, flew off after 4th pass, performs "territorial" flight display 35 sec after last pass. Returned to cliff 5:40 after last pass.	Uncertain	Alerted & perhaps flushed
		24 Feb	14:44	E-C	AF	A-7, 10 passes: 0-400 m horiz, -15 to 200 m up	AF flushed after 2nd pass, circled cliff through 3rd-10th passes (1 craft went 15 m below her), relit 31 sec after 10th pass	0:31 after last pass	Flushed
		12 Mar	10:50	M-C	AF	A-10, 4 passes: 50 m horiz, 0-80 m up	AF flushed on 1st pass, relit on 4th pass.	0:04 after 4th pass	Flushed: quickly relaxed
		12 Mar	11:45	M-C	AF	A-10, 4 passes: 50 m horiz, 0-20 m up	AF sleeked & crouched on some passes, elevated wings (flight intention movement) on one	0:34 preened after last pass	Alarm
		12 Mar	12:10	M-C	AF	A-10, 17 passes: 0-150 m horiz, 0-140 m up	AF intently watched each pass without sleeking	0:41 preen after last pass	Alert
		17 Mar	14:49	L-C	AF	F-104, 2 passes: 80-100 m horiz, 100-120 m up	AF continues perching & screaming AM arrives & prey exchange 1:07 after passes	0:00	Ignore
		17 Mar	15:26	L-C	AF	F-104, 2 passes: 40-70 m horiz, 80-100 m up	AF Watch few sec only	ca 0:05	Alert
		18 Mar	13:48	L-C	AF	A-10, 3 passes: 30-40 m horiz, 0-30 m up	AF watch ca 4 sec after each pass	ca 0:04	Alert

APPENDIX I (cont.)

Species	Site	Date	Time (hr:min)	Stage	Subject	Stimulus	Response	Duration of Interruption (min:sec)	Evaluation
	11:80	28 Mar	08:51	M-I	AF	A-7, 8 passes: 150-250 m horiz, 200 m up	AF watches craft, relaxed, incubating	0:00 no interruption	Watch only
		3 Apr	11:54	M-I	AM	F-4, 3 passes: 100-200 m horiz, 500 m up	AM incubating, no response determinable	0:00 no interruption	No change
		3 Apr	14:19	M-I	AM, AF	F-104, 4 passes: 400 m horiz, 1000 m up	AM incubating, continues, no response detectable	0:00 no changes, 1:06 AM doze, 1:17 AM fly to eyrie	No interruption detected
		19 May	15:29	L-N	2N	A-7, 4 passes: 150 m horiz, 200 m up	2Ns loafing at eyrie mouth, rush into cavity on 1st pass	2:56 N reappears at eyrie mouth	2N fled into eyrie
	11:81	24 Feb	10:10	E-C	AM, AF	A-10, 4 passes: 0-30 m horiz, 60-100 m up	AM flush on first pass, AF cower then cast 43 sec after last pass	AM?, AF 0:43	AM flushed AF alerted
		24 Feb	12:12	E-C	AF	A-10, 6 passes: 30-200 m horiz, 60-100 m up	AF walked into nest cavity after 2nd pass, flew off after 4th pass, performs "territorial" flight display 35 sec after last pass. Returned to cliff 5:40 after last pass.	Uncertain	Alerted & perhaps flushed
		24 Feb	14:44	E-C	AF	A-7, 10 passes: 0-400 m horiz, -15 to 200 m up	AF flushed after 2nd pass, circled cliff through 3rd-10th passes (1 craft went 15 m below her), relit 31 sec after 10th pass	0:31 after last pass	Flushed
		12 Mar	10:50	M-C	AF	A-10, 4 passes: 50 m horiz, 0-80 m up	AF flushed on 1st pass, relit on 4th pass.	0:04 after 4th pass	Flushed: quickly relaxed
		12 Mar	11:45	M-C	AF	A-10, 4 passes: 50 m horiz, 0-20 m up	AF sleeked & crouched on some passes, elevated wings (flight intention movement) on one	0:34 preened after last pass	Alarm
		12 Mar	12:10	M-C	AF	A-10, 17 passes: 0-150 m horiz, 0-140 m up	AF intently watched each pass without sleeking	0:41 preen after last pass	Alert
		17 Mar	14:49	L-C	AF	F-104, 2 passes: 80-100 m horiz, 100-120 m up	AF continues perching & screaming AM arrives & prey exchange 1:07 after passes	0:00	Ignore
		17 Mar	15:26	L-C	AF	F-104, 2 passes: 40-70 m horiz, 80-100 m up	AF Watch few sec only	ca 0:05	Alert
		18 Mar	13:48	L-C	AF	A-10, 3 passes: 30-40 m horiz, 0-30 m up	AF watch ca 4 sec after each pass	ca 0:04	Alert

APPENDIX I (cont.)

Species	Site	Date	Time (hr:min)	Stage	Subject	Stimulus	Response	Duration of interruption (min:sec)	Evaluation
		18 Mar	14:17	L-C	AF	A-10, 4 passes: 50-60 m horiz, 400-450 m up	AF watch ca 3 sec after each pass	ca 0:03	Alert
		18 Mar	14:52	L-C	AF, AM	A-10, 4 passes: 30-50 m horiz, 10-40 m up	AM soaring with prey, AF screaming before passes & 3 min after. Prey exchanged 4:05 after last pass.	4:05 until prey exchange resumed	Alert
		31 Mar	10:16	E-I	AM	A-10, 5 passes: 175-250 m horiz, 50-200 m up	AM incubating, ignore	0:00	Ignore
		7 Apr	13:58	M-I	AF	A-10, 8 passes: 70-150 m horiz, 0-80 m up	AF incubating, watch each pass a few sec	0:05	Alert
		8 Apr	08:37	M-I	AF	A-10, 2 passes: 100-150 m horiz, 0-50 m up	AF incubating, watch each pass 2-3 sec	0:03	Alert
		8 Apr	10:25	M-I	AF	A-10, 16 passes: 150-200 m horiz, 0-120 m up	AF incubating, ignores 1st pass, watches rest	ca 0:05	Ignore-Alert
		8 Apr	16:19	M-I	AF	A-10, 6 passes: 150 m horiz, 0-50 m up	AF incubating, watch each pass few sec	ca 0:05	Alert
		9 Apr	12:00	M-I	AM	A-10, 18 passes: 200-250 m horiz, 50-75 m up	AM incubating, rises from eggs on 1st pass & crouches preparing to fly. By third pass incubating & ignores pass. Watches each remaining pass a few sec.	ca 4:00 interruption of incubation	Alarm-Alert-Ignore
		14 Apr	11:10	M-I	AM	A-10, 4 passes: 200 m horiz, 70-100 m up	AM incubating, watches each pass	ca 0:05	Alert
		14 Apr	15:12	M-I	AF	A-10, 5 passes: 100-150 m horiz, 0-30 m up	AF incubating, watches each pass	ca 0:05	Alert
		15 Apr	15:34	M-I	AF	F-104, 1 pass: 250 m horiz, 0-10 m up	AF incubating, lowers head and watches	ca 0:05	Alarm
		23 Apr	10:34	L-I	AF	A-7, 8 passes: 200-300 m horiz, 0-80 m up	AF incubating, rises on 1st pass: cowers in nest hole, then stands & watches remaining passes until prey exchange 3:09 after last pass	ca 3:09?	Alarm
	12	25 Feb	12:03	M-C	AF	A-10, 4 passes: 70-300 m horiz, 0-50 m up	AF cowered and sleeked 3 sec on 1st pass then watch only	0:03	Alert-Alarm
		11 Mar	08:24	Lay	AF	A-10, 8 passes: 80-150 m horiz, 0-40 m up	AF watched only: preened 2:20 after passes	0:00	Alert

APPENDIX I (cont.)

Species	Site	Date	Time (hr:min)	Stage	Subject	Stimulus	Response	Duration of Interruption (min:sec)	Evaluation
		11 Mar	12:33	Lay	AF	A-10, 10 passes: 80-200 m horiz; 2 at 500 m up, 8 at eyrie level	AF watched each pass, looked at feet 57 sec after last pass	0:57	Alert
		19 Mar	13:41	E-I	AM	A-10, 13 passes: 50-100 m horiz, 0-30 m up	AM continues rock down as begins incubating, then ignores remaining passes	0:00	Ignore
		19 Mar	15:13	E-I	AF	A-10, 16 passes: 40-160 m horiz, 0-80 m up	AF continues incubation, ignores craft	0:00	Ignore
		19 Mar	17:13	E-I	AF	A-10, 4 passes: 40-80 m horiz, 0 m up	AF continues incubation, ignores craft	0:00	Ignore
		19 Mar	17:24	E-I	AM, AF	A-10, 6 passes: 0-40 m horiz, 0-1000 m up	After 4 passes, AF arose & left, AM settle to incubate	0:00	Both ignore
Peregrine	4:80	4 Mar	15:05	M-C	AM	A-7, 3 passes: #1 0 m horiz, 60 m up; #2-3 200 m horiz, 0 m up	AM perched on cliff, peers over shoulder trying to follow jet's passage	0:10 relaxed, 0:20 stoops at juv. golden eagle	Alerted
	5:80	3 Jun	08:49	M-N	AF	A-4, 2 passes: 300-350 m horiz, 180 m up	AF brooding chicks, watches without alarm	0:00 relaxed, brooding uninterrupted	Alerted
		3 Jun	09:44	M-N	AF	A-7, 2 passes: 600 m horiz, 0-50 m up	AF continues brooding chicks, watches craft, then looks away	0:00 relaxed	Watch, then looks away
		16 Jun	12:17	M-N	3N	A-10, 4 passes: 120-150 m horiz, 30-60 m up	2N (larger ones) run to wall and crouch on 1st pass, 1 N remains	2:40 N movements relaxed	Ns flee to wall and crouch
		16 Jun	14:26	M-N	3N	A-10, 2 passes: 100-120 m horiz, 30-60 m up	2N in mid eyrie, 1 N against wall at 1st pass, 2 exposed Ns run to wall (1 large & 1 small chick) and crouch	Within few minutes movements relaxed	Ns flee to wall and crouch
		16 Jun	14:39	M-N	3N	A-10, 2 passes: eyrie level, 50-100 m cut	1N asleep by wall & remains so, 2N near wall, move up against wall on first pass	1:15 1N walks parallel to wall. Behavior relaxed within a few min.	Ns flee to wall
	6:80	9 Jun	17:58	L-N/ E-PF	NF	A-10, 2 passes: overhead, 500 m up	NF moving about on eyrie lip. No change in behavior	0:00 relaxed, no change in behavior	No change
		10 Jun	10:08	E-PF	AF	A-10, 4 passes: 0-50 m horiz, 150-250 m up	AF perched near eyrie, sleeks & watches nervously at each pass	1:32 AF doze after 1st pass. 0:53 AF doze after 2nd pass.	Minor alarm

APPENDIX I (cont.)

Species	Site	Date	Time (hr:min)	Stage	Subject	Stimulus	Response	Duration of Interruption (min:sec)	Evaluation
	6:81	6 May	18:08	E-N	AM, AF	A-10, 9 passes: 0-400 m horiz, 130-300 m up	AM remains incubating out of sight. AF perching fluffed watches some passes	0:00-0:05	Alert-Ignore
		24 Jun	13:22	E-PF	2J	A-10, 7 passes: 0-400 m horiz, 0-300 m up	2Js fly together: 1 jet circles overhead 170-270 m up, 2nd jet repeatedly passes through area at falcon level. Falcons continue to soar without interruption.	None detected	Alert-Ignore
	23	13 May	10:00	N.A.	AF	A-10, 12 passes: 80-150 m horiz, 50-100 m up	AF remains perched, watches 7 passes, crouched (to fly?) on 6th, stretched after 6th	0:00-?	Alarm
	24	28 Apr	10:34	E-I	1A	A-10, 10 passes: 100-250 m horiz, 0-80 m up	1A remained incubating out of sight during passes	?	Did not flush
		28 Apr	13:32	E-I	1A	A-10, 6 passes: 250-300 m horiz, 0-200 m up	1A remained incubating out of sight during passes	?	Did not flush
	25	27 May	15:08	M-N	AF	A-10, 11 passes: 0-250 m horiz, 0-300 m up	AF perched on cliff near eyrie, flew out after 3rd pass, soared below 4th pass, perched, soared below 7th-8th pass, perched & protest called through last 3 passes	Extended period	Alarm-flush, protest called

APPENDIX II

STIMULUS-RESPONSE SUMMARIES FOR BOOMS

Species	Site	Date	Time (hr:min)	Stage	Subject	Stimulus	Response	Duration of Interruption (min:sec)	Evaluation
Black H	1	29 May	09:07	L-I	AF	Moderate sonic boom	AF brooding, looked toward sound source briefly	0:05 continues brooding	Alerted only
		29 May	10:16	L-I	AF	Very loud sonic boom	AF brooding, froze motionless 35 sec.	0:35 continues brooding	Alarmed only
Harris H	1:80	20 May	17:44	L-N	2N, 1A perched 100 m off	Mortar boom 200 m away (observors and rocket visible 200 m from A)	2N with heads high rapidly peer around; A rapidly exit from saguaro perch (results confused by visual stimuli)	1:06 Ns relaxed; 14 min A return to perch	Ns alerted: A fled
	1:81	6 May	09:38	L-N	1A, 2N	Propane cannon, 150 m observor near birds	A perched, Ns perched & lying; watched sound source few sec. then A ruffleshake	A 0:03 N no interruption	Alerted only
		6 May	09:57	L-N	3A[a]	Propane cannon, 150 m observor near birds	1A with prey, flushed from nest 1A remained perched 50 m from can. 1 A perched, flushed in ca 8 sec.	Gone 1.5 hour Short term Gone 1.5 hour	Flee Alerted only Flush
Zone-t H	1	10 Jul	10:22	L-N	2N	Mortar boom 300 m away	1N interrupts feeding bout, both N peer about	1:05 N1 resumes meal; 2 min N2 calls	Alerted
Red-t H	3	12 Mar	14:54	Lay	AF	Mortar boom 210 m horiz, rocket visible	AF sleeks feathers, rises slightly prepared to flee	0:32 relaxed visage; 0:58 yawn	Greatly alarmed, almost fled
		10 Apr	16:19	L-I	AM, AF	Mortar boom 210 m horiz, rocket visible	AM incubating elevates head and looks around intently until exit. AF returns to nest 33 sec after boom	AM alerted until exit; AF returns & settles to incubate	AM alarmed; AF returns to nest
	4	4 Apr	08:38	H-N	AF, 3N	Mortar boom, 100 m horiz	On launch-boom AF stopped feeding bout and lept out of nest; on second boom AF dodged in flight	0:23 AF returns to nest; 2:05 AF resumes meal	AF fled
G Eagle	1:80	21 May	15:52	L-N	2N	Mortar boom ca 30 m distant	2N watch after boom lying bird remains, standing bird moves 1 step toward cliff & crouches with head lowered 1 min.	ca 1:00 head back up to normal posture	Standing N cowers
	1:81	8 May	12:55	M-N	1A	Propane cannon, 375 m observor near birds	A perched on cliff, flinched, looked, crouched, flushed, circled cliff front & lost out of sight	Gone 1.1 hour	Flee
Prairie F	1:80	20 May	08:08	L-N	N	Mortar boom 70 m away	N interrupts meal	1:10 begins meal again	Alerted N

Species	Site	Date	Time (hr:min)	Stage	Subject	Stimulus	Response	Duration of Interruption (min:sec)	Evaluation
	4:80	26 Mar	08:20	E-I	AF	Loud sonic boom	AF incubating, lifts head slightly and looks rapidly about	0:41 yawn	Alerted
		26 Mar	11:28	E-I	AF	Very loud sonic boom	AF perching, lifts head slightly and looks rapidly about	Continues incubation	Alerted
		26 Mar	12:45	E-I	AF, AM	Very loud sonic boom	AF perching, looks rapidly about, interrupts preen bout; AM incubating, continues without response	0:20 AF scratch; 0:00 AM no interruption	AF alerted AM no response
	4:81	18 Feb	15:55	M-C	AM	Mortar boom, 300 m, flash visible	AM flush & fly 17 min before relighting	Prob. 16:44	Flush
		3 Mar	10:05	L C	prob AF	Very loud sonic boom	AF flushed but relit in 4 sec Alerted for ca 1 min.	Ca 1 min	Flush
		4 Mar	12:44	L-C	AF	Moderate sonic boom	AF perched on cliff, ignores boom	0:00 none identified	Ignore
		4 Mar	16:22	L-C	AF, AM	Moderate sonic boom	Both A's ignore	0:00 none identified	Ignore
		6 May	12:47	M-N	AF, 2N	Propane cannon, 300 m	AF perched near eyrie; jerks head & looks around few sec.; Ns remain lying down	ca 0:05	Alerted only
		6 May	13:14	M-N	AF	Propane cannon, 300 m, 2 booms, 15 sec apart	AF feeding young, pause 1 sec. on first boom; less on second	ca 0:01	Alerted-Ignore
		6 May	14:41	M-N	prob AF	Propane cannon, 300 m	AF perched by eyrie, glances toward sound source	At most 0:05	Alerted only
	7	6 May	11:25	N.A.	A	Propane cannon, 200 m observer visible	A preening, flushes and flies for ca 4 min.	Ca 4 min.	Flush
		6 May	12:11	N.A.	A	Propane cannon, 200 m observer visible	A perched, crouched in preparation for flight ca 3 sec.	0:03	Alarm
		6 May	12:45	N.A.	2A	Propane cannon, 200 m observer visible	AF flushed & left area; AM remained on cliff	AF gone 1.25 hr. AM gave brief response	AF flee AM alarm
	10	11 Apr	11:14	I	AF	Mortar boom ca 75 m away	AF incubating, lifts head and watch intently out and up	1:27 eyerub & headshake 1:47 head lower, relax	Alerted
	11:80	3 Apr	09:19	M-I	AF	Mortar boom 70 m away	AF incubating, head elevated, looks out with head rapidly turning side to side	1:16 head lower; 3:35 begins dozing	Alerted

APPENDIX II (cont.)

Species	Site	Date	Time (hr:min)	Stage	Subject	Stimulus	Response	Duration of Interruption (min:sec)	Evaluation
		3 Apr	12:46	M-I	AM	Moderate sonic boom	AM settling to incubate, continues rocking down onto eggs after 15 sec. pause	0:15 continues rock down to incubate	Pause only
		3 Apr	13:26	M-I	AF	Mortar boom 70 m away	AF incubating, lifts head & peers out while turning head side to side	0:25 headshake and fluffed, relaxed	Alerted .5 min.
		19 May	16:17	L-N	AM, 1N	Mortar boom 70 m away, visible to AM	AM leaves perch & soars overhead; N rises to sit, looks into eyrie	Transitional behavior	AM flew out; N arose
	11:81	8 Apr	10:59	M-I	AF	Propane cannon, 100 m	AF incubating, rises walks to eyrie entrance then returns	ca 4 min.	Alarm
		8 Apr	11:18	M-I	AF	Propane cannon, 100 m	AF incubating, flinches & lowers head ca 2 sec.	0:02	Alarm
		8 Apr	11:34	M-I	AF	Propane cannon, 100 m	AF incubating, flinches & raises head ca 2 sec.	0:02	Alarm
		8 Apr	11:46	M-I	AF	Mortar boom, 1000 m	AF incubating, rises from eggs walks to eyrie entrance 7 min. returns to eggs	ca 7 min.	Alarm
		9 Apr	12:55	M-I	AF	Propane cannon, 300 m: 3 booms	AF remains incubating, watching sound source	Continues incubation	Alerted
		9 Apr	13:22	M-I	AF	Propane cannon, 300 m: 1 boom	AF remains incubating, watching sound source	Continues incubation	Alerted
		9 Apr	13:48	M-I	AF	As above	As above	As above	As above
		9 Apr	16:01	M-I	AF	As above	As above	As above	As above
		9 Apr	17:24	M-I	AF	As above	As above	As above	As above
		9 Apr	17:52	M-I	AF	As above	As above	As above	As above
		9 Apr	18:03	M-I	AF	As above: 3 booms	As above	As above	As above
		9 Apr	18:14	M-I	AF	As above: 5 booms	As above	As above	As above
		9 Apr	19:14	M-I	AF	As above: 7 booms	As above	As above	As above
		10 Apr	09:25	M-I	AF	Moderate sonic boom	AF incubating, elevates head & peers out ca 7 sec.	0:07	Alert

APPENDIX II (cont.)

Species	Site	Date	Time (hr:min)	Stage	Subject	Stimulus	Response	Duration of Interruption (min:sec)	Evaluation
		16 Apr	14:58	M-I	AF	Mortar boom, 300 m	AF incubating, looks rapidly side to side	1 min.	Alarm
		22 Apr	17:33	L-I	AF	Mortar boom, 300 m	AF incubating, leaves eggs & stands in eyrie entrance 3 min.	ca 3 min.	Alarm
Peregrine	1:80	15 May	16:45	L-I	AM, AF	Mortar boom ca 300 m away	A incubating out of sight, did not leave ledge	No changes observed. A out of sight	No flush
	1:81	28 Mar	18:52	M-C	AM, AF	Mortar boom, 1100 m	2As soar in then settle to roost, neither flushes (only 1 visible on boom)	None detected	No flush
	4:80	3 Jul	10:00	PF	AM, 2J	Mortar boom 100-200 m away, rocket and observor visible	AM perched on cliff 100 m away, JM perched 150 m away, JF perched 200 m away, all flee	In ½ min all circle 400 m S of boom. In 3 min all circle overhead.	2J, AM flee, rocket and boom visible
	4:81	2 Jun	15:34	N.A.	AF	Mortar boom, 400 m	AF preening, flushes, flies along cliff & perches in 15 sec.	0:15	Flush
	5:80	3 Jun	10:53	M-N	AM, AF	Mortar boom 100 m away, observors visible to flying male	AF incubating, elevates head, rises to sit, continues to incubate. AM perched on cliff, flies out, soars & protest calls a few times, circles off.	1:30 AF watches still but relaxed. 0:50 AM circles out and lost	AF alarmed & rises to sit incubate. AM flies out, protest calls
		16 Jun	10:29	M-N	AF, 3N	Mortar boom 100 m away, observors visible	AF continues to feed young without interruption during boom (looks up 1 sec. at each boom)	0:01 AF continues meal	No interruption of meal
	6:81	24 Jun	14:27	PF	JF	Shotgun, 150 m away	JF perching, jerks head up & looks rapidly about 1:12	1:12	Alarm
		24 Jun	15:11	PF	JM, JF	Shotgun, 150 m away	JM perching, crouches & looks rapidly about; JF also remains	ca 0:25	Alarm
	7	26 Mar	09:33	L-C	AF	Propane cannon, 100 m	AF feeding, immediately flushes, glides in area ca 2 min, then leaves	Gone 1.3 hrs.	Flush
		26 Mar	10:42	L-C	AM	Propane cannon, 150 m	AM gliding, dodges for an instant in flight, then continues glide	00:01	Alarm(?)
		8 Jul	15:36	PF	JM	Shotgun, 80 m away	JM perching, immediately flushes then soars in area 9 min until lost	Gone 2.8 hr.	Flush
	8	13 Apr	14:22	Lay	AM	Propane cannon, 100 m observer visible	AM perched, flushes & circles in chasm nearly 2 min, relights	1:55	Flush

APPENDIX II (conc.)

Species	Site	Date	Time (hr:min)	Stage	Subject	Stimulus	Response	Duration of Interruption (min:sec)	Evaluation
		13 Apr	14:51	Lay	AM	Propane cannon, 150 m Observer visible	AM perched, flushes & circles & protest calls 4 min.	ca 4 min.	Flush
		18 Jun	12:42	L-N	AF, 4N	Mortar boom, 120 m observer visible	AF feeding Ns, AF looks about ca 5 sec: oldest N looking about ca 10 sec. All quickly resume meal	0:05	Alert
	23	13 May	06:46	N.A.	AM, AF	Mortar boom, 300 m	AM perching, flushes & circles screaming 2.5 min. AF perching, flushes & circles out of sight	Ca 2.5 min.	Flush
	25	27 May	13:05	M-N	AF	Mortar boom, 120 m	AF feeding young, flushes with prey 4 sec. after boom, reenters eyrie in 1:33, resumes meal in 1:45	01:45	Flush
	27	19 Jun	13:41	L-N	AF	Shotgun, 130 m away	AF perching, quickly flashes wings out & peers about rapidly, wings closed within 1 sec, calm by 1:40	ca 01:40	Alarm
	28	25 Mar	11:07	L-C	AM, AF	Mortar boom, 600 m	Both As perched, remain on perch .5 hour	ca 0:00	Alert
		25 Mar	11:57	L-C	AM, AF	Mortar boom, 600 m	Both As perched, remain but AF look rapidly about ca 10 sec. AM watch only	0:10	AF Alarm AM Alert